University of the State of New York

BULLETIN

OF THE

New York State Museum

FREDERICK J. H. MERRILL *Director*

No. 45 Vol. 9

April 1901

GUIDE TO THE

GEOLOGY AND PALEONTOLOGY

OF

NIAGARA FALLS AND VICINITY

BY

AMADEUS W. GRABAU S.D.

Professor of geology Rensselaer polytechnic institute, and lecturer in geology Tufts college

WITH A CHAPTER ON

POST-PLIOCENE FOSSILS OF NIAGARA

BY

ELIZABETH J. LETSON

Director of the museum, Buffalo society of natural sciences

ALBANY

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REGENTS

With years of election

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PREFACE

With the support and cooperation of the Buffalo society of natural sciences and the department of paleontology of the state museum, Dr Grabau has prepared this guide to the geology and paleontology of Niagara falls and vicinity with the special purpose of affording to visitors to Buffalo during the season of the Pan-American exposition in 1901 a viaticum in their tours through this region renowned for its scenic features and classic in its geology. The ground has been the subject of a multitude of scientific treatises concerned now with the succession of events in the upbuilding of the rock strata along the canyon of the river; again with the nature of the organic remains inclosed in these strata; sometimes with the changes which the falls have undergone in historic times, but for the most part with the perplexing problems of the origin of the present drainage over the great escarpment and through the gorge, the raison d'être of the falls, the various changes in the course and work of the Niagara river since its birth and the significance of the present topography of the region. These scientific investigations began with the careful surveys instituted by the late Prof. James Hall, state geologist and paleontologist, during the years of his explorations in the 4th geologic district of this state from 1837-43, who, in addition to his record of the work done by this tremendous agent, derived from this region an important term in the New York series of rock formations, the Niagara group, and portrayed the organisms of the various strata which are so superbly exposed along its great channel. Lyell and Bigsby, Logan, Gilbert, Upham, Spencer, Leverett and Taylor are among the names of others who have contributed, from various points of view, facts and hypotheses relating to the geologic history of the river. In no one place however has the general purport of all these various studies been brought together so that the intelligent traveler or student can acquire them in convenient form. It is for this reason that Dr Grabau's work in bringing together in concise form the essence of these investigations, tempered and proved by his own review of them in the field, will not fail to prove serviceable to a large element of the public.

JOHN M. CLARKE

State paleontologist

Plate 1

Niagara falls from Father Hennepin's view point

INTRODUCTION —NIAGARA FALLS

AND

HOW TO SEE THEM[1]

The falls of Niagara have been known to the world for more than 200 years. Who the first white man was that saw the great cataracts is not known, but the first to leave a description was the French missionary, Father Louis Hennepin, who, in company with La Salle, visited the falls in 1678. He was the first white man to use the name, Niagara, for the river and the falls, a name which had been applied by the Neuter Indians, who occupied the territory on both sides of the river prior to the year 1651, when they were conquered by the Senecas, who after that occupied and possessed the territory.[2] In the native language the name is said to signify "the thunder of the waters".

The first sight of the great cataracts must have made a powerful impression on Father Hennepin, unprepared as he was by previous descriptions save those given him by his Indian allies and guides. He speaks of the falls as "a vast and prodigious Cadence of Water which falls down after a surprizing and astonishing manner, insomuch that the Universe does not afford its Parallel".[3] He considered the falls "above Six hundred foot high", and adds that "the Waters which fall from this horrible Precipice, do foam and boyl after the most hideous manner imaginable, making an outrageous Noise, more terrible than that of Thunder, for when the

[1]Niagara falls are reached from Buffalo by train or electric cars, both of which run at frequent intervals. A direct line of railway runs from Rochester to the falls by way of Lockport. Direct railway connection with western cities is obtained by way of Suspension bridge, while from Toronto and other cities north of Lake Ontario the falls may be reached by train direct, or by boat to Lewiston or Queenston, and thence by train or electric road to Niagara. All electric cars on the New York side run to or past Prospect park, and most of them pass the railway stations. The railway stations are within walking distance of the falls.

[2]Porter, Peter A. Goat island. 16th an. rep't comr's state reservation, 1900.

[3]A new discovery of a vast country in America. 1698. p. 29. Reprinted in part in special report N. Y. state survey for 1879.

Wind blows out of the South, their dismal roaring may be heard more than Fifteen Leagues off."[1]

If today, from our vantage ground of precise knowledge, we smile on the extravagant estimates of Father Hennepin, it may be asked, who among us, that is capable of admiration and enthusiasm at the sight of nature's grand spectacles, would, on coming unprepared on these great cataracts, be able to form a calm and just estimate of hight and breadth and volume of sound?

Since the time of La Salle and Hennepin, the falls have been viewed by a constantly increasing number of visitors. For Americans of the present generation and for people of other lands as well, Niagara has become a sort of Mecca, to which they hope once in their life time to journey. With many this is a hope long deferred in realization, with most perhaps it is a dream never realized, but those who do go and see, come away with their conceptions of nature much enlarged and with memories which cling to the end of life. Fully to appreciate Niagara, one must give it more than a passing glance from the carriage of an impatient driver, who is anxious to have you " do " Niagara in as short time as possible, that he may secure another " fare ". Learn to linger at Niagara, and give nature time to impress you with her beauty and her majesty. " Time and close acquaintanceship," says Tyndall, " the gradual interweaving of mind and nature, must powerfully influence any final estimate of the scene ". And the growing impression which this incomparable scene produced on him, served to strengthen the desire " to see and know Niagara falls as far as it is possible for them to be seen and known".[2]

It is surprising that many of the visitors to the falls allow themselves to be hurried past some of its most beautiful spots and to bestow on others only casual attention, and then waste a wholly disproportionate amount of time in the museums and curio stores looking for souvenirs purporting to come from Niagara but generally manufactured elsewhere. Real and valuable Niagara souvenirs may be had for the trouble of picking them up, in the minerals, fossils and shells which abound in the vicinity of the falls.

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[1] *Loc. cit.*

[2] Tyndall. Fragments of science, " Niagara ".

Plate 2

Luna falls, and the limestone fragments at its base (Copyright by Underwood & Underwood, New York)

And, while one gathers these, one's knowledge of Niagara becomes broadened, and the perception grows that there are other lessons to be learned in this region, lessons of even more tremendous import than those taught by the cataracts.

The pedestrian has by far the best opportunity to see and enjoy nature as she is only to be seen and enjoyed at Niagara. The stately forest beauty of Goat island, unequaled in the estimation of those competent to judge, by that of any other wooded spot of similar size; the constantly changing views of gorge and falls and rapids which are obtained from nearly every path on the islands and the mainland on both sides of the river; the magnificence of the turbulent waters as they rush toward you, wave piling on wave, till it seems as if the frail-looking structure on which you stand must inevitably be carried away by them—none can enjoy these to their full extent while sitting in a carriage, though it move never so slowly, or while being compelled to listen to the descriptions and explanations of an unsympathetic and unappreciative driver. If you must ride, patronize the reservation carriages, which leave you wherever you wish to stop and take you on again at your own pleasure.[1]

Views from the New York side

The first view of the falls which the visitor on the New York side enjoys is generally from Prospect point, or some of the more elevated view points along the brink of the gorge in Prospect park (*see* frontispiece, pl. 1). While impressive, this view by no means reveals to its full extent the matchless grandeur of the cataracts, and in this respect the visitor on the Canadian side has the advantage. However, the views from Prospect point and Father Hennepin's view point should be obtained by every one, and it may be that some will find greater attraction in these than in the more comprehensive views obtained from the other side. While in Prospect park, it is well to descend to the foot of the inclined railway, and get the views

[1] These carriages are run at intervals of 15 minutes, starting from Prospect park, and making the circuit of Goat island. The fare is 15c for the round trip, and stop-overs at all places, and for any length of time on the same day, are allowed.

of the falls from below. The ride on the *Maid of the Mist* will be found an interesting and novel experience, besides affording views of the cataracts obtainable in no other way; but most people will defer this till they have seen more of the cataracts and rapids from above. In visiting the foot of the falls, an umbrella should be taken, while a waterproof cloak will be found of great advantage, for the visitor is apt to be drenched by the spray which will be blown on him unawares. Caution is necessary here, as everywhere at Niagara, to avoid accidents. In the talus heaps of limestone fragments, minerals and occasionally fossils may be found.

From Prospect point the visitor should next turn his attention to Goat island, "the most interesting spot in all America", as Capt. Basil Hall called it. The unpoetic name of this island is, as Mr Porter tells us[1], commemorative of the power of endurance of a male goat, which, in company with a number of other animals, had been left on this island uncared for during the severe winter of 1770-71, and proved the only survivor.

From the bridges which cross to Green, and thence to Goat island, memorable views of the rapids above the falls may be obtained; and the visitor will do well to pause, that he may become impressed by the magnificence of the spectacle. Perhaps he will feel as did Margaret Fuller, who said: "This was the climax of the effect which the falls produced upon me—neither the American nor British fall moved me as did these rapids." The naturalist will be interested to note that, in spite of the fearful rush of water, fresh-water mussels have found a lodging place among the more protected rocks, where they seem to thrive well. Along the shores of the islands, in places where other animals would find it hard to gain a foothold, numerous small gastropods may be found clinging to the slippery rock surfaces.

On Goat island, despite the so-called "improvements" for the convenience of visitors, nature still reigns supreme. The virgin character of the forest is almost undisturbed, as it was when the red man regarded this as the sacred abode of the Great Spirit of

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[1] Porter. Goat island.

Niagara. The botanist will here find a greater variety of plants within a given space than in almost any other district.[1]

But it is in the wonderful views of the falls and the rapids and the gorge which can be obtained from this island, that its chief attraction lies. The various view points are easily found, and the stroller about Goat island would best come on them unawares. Mention may be made of the glimpses of the American falls obtained from the head of the stairway leading to Luna island, as well as from the island itself, and the panorama of rapids, falls and gorge from the Terrapin rocks at the edge of the Horseshoe falls. Every visitor is advised to descend the Biddle stairway and view the falls from below. No charge is made unless one wishes to enter the Cave of the winds, a most thrilling experience for a person of nerve and one unparalleled by any other which may legitimately be obtained at Niagara. But, even if one does not care to go behind the falls, a visit to the foot of the stairway, and a walk along the path at the base of the vertical cliff of limestone will well repay the exertion of the climb. Many noble views of the gorge and the falls may be obtained from the stairway, while from certain points below, impressive sights of the small central fall are to be had. Here too can be seen the undermining action of the spray, which removes the soft shale, leaving the limestone ledges projecting till in the course of time they fall for want of support. On the talus slopes at the foot of the cliff good specimens of minerals and occasional fossils may generally be obtained.

After leaving the Biddle stairway, and the Terrapin rocks, the visitor will proceed southward along the river bank to the bridge leading to the Three Sister islands. On the way the geologist will pause where a wood-road leads off to the left into the famous gravel pit of Goat island, since there the shell-bearing gravels are exposed.[2]

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[1]A catalogue of the flowering and fern-like plants growing without cultivation in the vicinity of the falls of Niagara, by David F. Day, is published in the 14th annual report of the commissioners of the state reservation. In this a total of 909 species are recorded, a large proportion of which are credited to Goat island.

[2]These shells are described in chapter 5.

A small fall known as "The Hermit's cascade" lies between Goat island and the First Sister. In the pool at the foot of this fall Francis Abbot, the Hermit of Niagara, was wont to take his daily bath.

From the bridges and from the islands unsurpassed views of the upper rapids are obtained. These are particularly impressive when seen from the rocks of the Third Sister. Of these rapids as seen from the Terrapin rocks, the Duke of Argyle wrote:

When we stand at any point near the edge of the falls, and look up the course of the stream, the foaming waters of the rapids constitute the sky line. No indication of land is visible—nothing to express the fact that we are looking at a river. The crests of the breakers, the leaping and the rushing of the waters, are still seen against the clouds as they are seen in the ocean, when the ship from which we look is in the trough of the sea. It is impossible to resist the effect of the imagination. It is as if the fountains of the great deep were being broken up, and that a new deluge were coming on the world. The impression is rather increased than diminished by the perspective of the low wooded banks on either shore, running down to a vanishing point and seeming to be lost in the advancing waters. An apparently shoreless sea tumbling toward one is a very grand and a very awful sight. Forgetting, then, what one knows, and giving oneself to what one only sees, I do not know that there is anything in nature more majestic than the view of the rapids above the falls of the Niagara.

On returning to Goat island the visitor may take the reservation carriage for a return to Prospect park, or he may continue his walks around or across Goat island.

In front of Prospect park the electric cars may be taken to cross the river, the bridge-toll which every foot passenger has to pay, being included in the car fare.

Views from the Canadian side

The Canadian side is reached either by bridge or by the steamer *Maid of the Mist*.[1] Every visitor to the falls should obtain the views from the Canadian side, which are in many respects superior to any obtainable on the New York side. Several rustic arbors have been constructed along the brink of the gorge in Queen Victoria park, and here the visitor may tarry for hours and not weary of

[1] If the visitor plans to take the belt line ride—Niagara, Queenston, Lewiston—he will have opportunity to stop off in Queen Victoria park, and need not make a special crossing.

the sights he beholds. The remarkable vivid green of the water of the Horseshoe falls will excite the observer's interest, and question. Tyndall observes that, while the water of the falls as a whole "bends solidly over and falls in a continuous layer. . . close to the ledge over which the water rolls, foam is generated, the light falling upon which, and flashing back from it, is sifted in its passage to and fro, and changed from white to emerald-green."[1]

Near the edge of the Horseshoe falls are the remains of Table rock, formerly a projecting limestone shelf of considerable extent, and a favorite view point. Huge portions of this rock have fallen into the gorge at various times, the most extensive falls occurring in 1818 and 1850, with minor ones between and since. On one occasion some forty or fifty persons had barely left the rock before it fell. From the remaining portion of this rocky platform a good near view of the Horseshoe falls is obtained, though the visitor is apt to find himself in a drenching shower of spray at almost all times.

Beyond Table rock, in the upper end of the park, and on the Dufferin islands many attractive walks are to be met with. These are generally little visited and afford an opportunity for solitude and escape from the crowds of sightseers. Some of the best views of the rapids above the falls are to be obtained here. A wooded clay cliff bounds the park on the landward side, generally rising steeply to the upland plateau. Here on July 25, 1814, the memorable battle of Lundy's Lane was fought between the British and the Americans; "within sight of the falls, in the glory of the light of a full moon, the opposing armies engaged in hand-to-hand conflict, from sundown to midnight, when both sides, exhausted by their efforts, withdrew from the field".[2]

At the head of the park, a road leads to the upland, where is situated the famous burning spring. The inflammable gas which here bubbles through the water of the spring is chiefly sulfureted hydrogen, but the quantity is such as to produce a flame of considerable magnitude, and it is asserted that the supply has not diminished for the hundred years or more that the spring has been known to exist.[3]

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[1] *Loc. cit.*

[2] Porter.

[3] An admission fee is charged here.

The gorge below the falls

The gorge of the Niagara river should be seen from both sides. Here as elsewhere the pedestrian with abundant time has the best opportunity to see the numerous interesting and attractive features; but, since distances here are considerable, it is perhaps more advisable to avail one's self of the conveyances afforded.[1]

The best view of the gorge is afforded by going down the river on the Canadian side and returning by the gorge road. In this way the passenger on the cars gets nearest to the river, particularly if the right hand seats are selected. If the visitor however prefers to go down the river on the gorge road, and return by the Canadian line, let him choose the left side of the cars as nearest to the river in both cases.

After passing Clifton on the Canadian side, and the last of the bridges which here span the gorge, the observer begins to have a view of the whirlpool rapids, which even from this elevation have a threatening aspect. It was through these rapids and through the whirlpool below, that the first *Maid of the Mist* was safely navigated in 1861, having at the time three men on board—a feat which has never been repeated. Through this same stretch of rapids Capt. Webb made his fatal swim, paying for the foolhardy attempt with his life. After passing the rapids we reach the whirlpool, of which good views are afforded from many places along the top of the bank. After crossing several small ravines, that of Bowmans creek is reached. This ravine is a partial reexcavation of the old drift that filled St Davids channel.[2] From the upper end of the bridge which crosses the ravine, a path leads down to the water's edge, the ravine being one of singular attractiveness to the lover of wild woodland scenery. A short distance beyond the bridge is the Whirlpool station of the electric road. Here, from a little shelter built on the extreme point, fine views of the whirlpool and the river above and below it are obtained. The river here makes a right-angled bend, the whirlpool forming the swollen elbow. In the rocky point projecting from the

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[1] The visitor will do well to purchase a belt line ticket, which entitles him to make the circuit in either direction and to stop at all important points. The Canadian scenic route will take him along the top of the bank, while the gorge road, on the New York side, takes him close to the edge of the water.

[2] *See* map, and chapter I.

bank on the New York side the succession of strata is finely shown[1]; and from this point northward the New York bank exposes a nearly continuous section as far as the mouth of the gorge at Lewiston.

A short distance below the whirlpool we reach Foster's flats, or Niagara glen, as it is more appropriately called. This is visited by comparatively few tourists, though it is one of the most attractive spots along the gorge.[2] It marks the site of a former fall, and, besides its interest on that account deserves to be visited for its silvan beauty and its wild and picturesque scenery of frowning cliff, huge moss-covered boulders and dark cool dells, where rare flowers and ferns are among the attractions which delight the naturalist. Many good views of the river and the opposite banks may here be obtained, and the student of geology will find no end to instructive features eloquent of the time when the falling waters were dashed into spray on the boulders among which he now wanders. After leaving Niagara glen the visitor should stop at Queenston hights and obtain the view which is here afforded.[3] If possible the more comprehensive views from the summit of Brock's monument should be obtained.[4]

After descending and crossing to the New York side, one may return directly by the gorge road, leaving the inspection of the fossiliferous strata for another day, or one may, after a rest at the hotel, or on the river bank, spend some hours in studying the sections exposed along the New York Central railroad cut.[5]

The return journey by the gorge road is one of great interest, as it carries the visitor close to the rushing waters of the river. Walking along the roadbed is forbidden, and stops are made only at the regular stations.[6] The first of these is the Devil's hole, a cavern in the rock, of the type described in chapter 3 and supposed to have figured in Indian lore. The ravine of Bloody run, a small stream generally dry during the summer season, was the scene of a fearful massacre of the English soldiers by the Seneca Indians in 1763, the

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[1] For a description of these, *see* chapter 3.

[2] *See* chapter 2.

[3] *See* chapter 1.

[4] An admission fee is charged here.

[5] Waggoner's hotel near the Lewiston suspension bridge makes a convenient stopping place, specially if one desires to visit the fossiliferous sections. The Cornell, at the ferry landing, opposite the Lewiston railroad station, is also recommended.

[6] In stopping off, be sure to obtain stop-over checks from the conductor.

whole party with the exception of two, with wagons and horses, being driven over the cliff by the savages, and dashed to pieces on the rocks below. Next above the Devil's hole is Ongiara[1] park, a picturesque wooded slope opposite the southern end of Foster's flats, and like parts of that region are dotted with enormous blocks of limestone, which have fallen from the bank above. A short distance above this we come to the whirlpool, where a stop of some time can profitably be made. But by far the most attractive place at which to stop is the whirlpool rapids. The water which here rushes through a narrow and comparatively shallow channel, makes a descent of nearly 50 feet in the space of less than a mile, and its turbulence and magnificence are indescribable. Seen at night by moonlight, or when illuminated by the light from a strong reflector, the spectacle is beyond portrayal. We may perhaps not inaptly apply Schiller's description of the Charybdis to these waters:

Und es wallet und siedet und brauset und zischt,
Wie wenn Wasser mit Feur sich mengt.
Bis zum Himmel spritzet der dampfende Gischt,
Und Well' auf Well' sich ohn' Ende drängt,
Und wie mit des fernen Donner's Getose,
Entstürzt es brüllend dem finstern Schosse.

Fossiliferous sections

These sections are to be seen on the cut of the New York Central and Hudson river railroad, Lewiston branch, and along cuts of the Rome, Watertown and Ogdensburg railroad at Lewiston hights. The former are approachable from Lewiston on the north or the Devil's hole station on the south. The approach from Lewiston is the more natural, as it will give the strata in ascending order. Waggoner's hotel makes a convenient starting point. Follow the car tracks southward to where a road leads off on the left. Entering this, a wood-road is found to lead off on the right, which when followed will bring you on the terrace formed by the quartzose sandstone bed, and on which the bridge towers stand. A quarry in the white sandstone by the roadside gives an opportunity to study this rock, which is practically barren of fossils. Beyond this the tracks of the New York Central railroad are reached, which, after traversing a short tunnel hewn out of the Medina sandstone, bring you to the sections in the gorge (plate 12). Care must be exercised in exploring

[1] One of the 40 ways of spelling Niagara.

these sections, as trains are frequent, and rockfalls from the cliffs are among the daily occurrences. With a little caution however the sections may be studied without danger. The total amount of walking necessary from Waggoner's hotel to the Devil's hole is about 3 miles. Near the upper end of the section, where the track enters a rock cutting, a steep path along the river bank leads to the top of the rocky plateau, and a short walk along the top of the bank will bring you to the Devil's hole station. One may also climb the bank in the quarry at the head of the section, and, passing along the top, reach the Devil's hole station by crossing the bridge over the rock-cut before mentioned. At the Devil's hole station[1] one may either take the surface car, which runs to Niagara falls at frequent intervals (5c fare), or, by paying the admission to the Devil's hole, descend to the gorge road and continue the journey to the falls. (A ticket or 50c fare is required here.)

If the sections are approached from the upper end, the Devil's hole station may be reached by the surface electrics[2] or the visitor may leave the cars of the gorge road at the lower Devil's hole station, and, paying the admission fee, ascend the banks by the stairs and paths. The path from the Devil's hole station to the sections leads close along the brink of the gorge. If the sections are visited in the forenoon, the investigator will find himself in the shadow of the cliffs, which is most grateful on a warm summer day.

The sections on the Rome, Watertown and Ogdensburg railroad are reached from Waggoner's hotel by paths leading up " the mountain " one of which begins on the New York Central tracks not far north of the tunnel.

Geologic nomenclature

Geologic time is divided into five great divisions, based on the progress of life during the continuance of each. These are:

5 Cenozoic time, or time of " modern life "
4 Mesozoic time, or time of " medieval life "
3 Paleozoic time, or time of " ancient life "
2 Proterozoic time, or time of " first life "
1 Azoic time, or time of " no life "

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[1] Refreshments may be obtained here.

[2] These electrics run from near Prospect park to the Devil's hole and return, at short intervals.

Each of these time divisions is farther divided into great eras, those of Paleozoic time being given in the annexed table. Each era is in general divisible into three periods of time, the early, middle, and later, for which the prefixes *paleo* (or *eo*), *meso* and *neo* are used. The farther division of the periods is into epochs.

During the continuance of each great time division of the geologic history of the earth, more or less extensive rock systems were deposited, wherever the conditions were favorable. Thus the Paleozoic rock system is that deposited during Paleozoic time. That part of the Paleozoic rock system which was deposited during the Siluric era, is called the Siluric rock series, and similarly, the name of each of the other great *eras* is also applied to the rock series deposited during its continuance. In like manner each geologic *period* has its corresponding *group* of rocks deposited during its continuance. These rock groups and their farther subdivision into stages have, in New York, received local names, the name of the locality where the rocks are best developed being selected. The rocks formed during Proterozoic and Azoic time are generally spoken of as pre-Cambric.

The following table embodies the result of the latest studies.[1] The thicknesses are chiefly obtained from well records published by Prof. I. P. Bishop. The relations of these strata to each other in this region are shown in the north and south section from Canada to the New York-Pennsylvania line, presented in fig. 1.

Ever since the days of Lyell and Hall the life history of Niagara and the origin of the Great lakes has engaged the attention of geologists the world over. Among the names prominent in connection with studies of the geology of Niagara in one or more of its aspects, may be mentioned those of Bishop, Clarke, Claypole, Davis, Fairchild, Gilbert, Hall, Hitchcock, Lesley, Lyell, Newberry, Pohlman, Ringueberg, Shaler, Spencer, Tarr, Taylor, Upham and Wright, besides a host of others.[2]

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[1] Clarke and Schuchert. Science. n. s. Dec. 15, 1899, 10:3. It will be found to differ in some respects from the table published in the author's Geology of Eighteen Mile creek, etc.

[2] In the field work I have had the efficient assistance of my friend Mr R. F. Morgan of Buffalo.

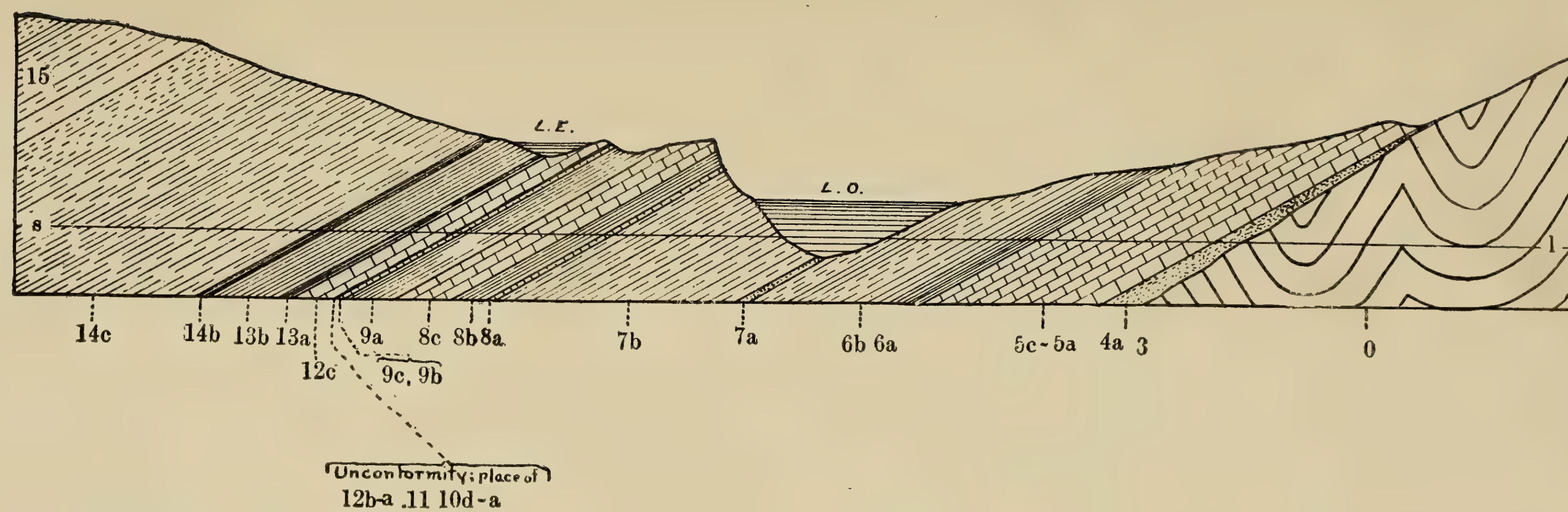

Fig. 1 Section from the Canadian highlands across western New York to the Pennsylvania line, showing the succession of strata. The numbering of the beds corresponds to that of the succeeding table. Owing to the great exaggeration of the vertical over the horizontal scale, the dip of the strata appears much too steep. s l. = sea-level, L. E. = Lake Erie, L. O. = Lake Ontario. Horizontal scale 1 inch = 38 miles. Vertical scale, 1 inch = 1500 feet.

Table of Paleozoic subdivisions

Time scale	Formation scale	New York state rock equivalents	Thickness in the Niagara region
Paleozoic time	*Paleozoic system*		
5 Carbonic era	5 Carbonic series		
c Neocarbonic period	*c* Upper Carbonic group	Absent in New York	....
b Mesocarbonic period	*b* Middle Carbonic group	"	....
a Paleocarbonic period	*a* Lower Carbonic group	"	....
4 Devonic era	4 Devonic series		
c Neodevonic period	*c* Upper Devonic group	*c* Upper Devonic group	
		15 Chautauquan subgroup	?
		15a Chemung beds (Catskill sandstone, local facies)	....
		14 Senecan subgroup	
		14c Portage beds	
		3) Oneonta beds } local facies	
		2) Ithaca beds } local facies	938′ to 1541′
		1) Naples beds } local facies	
		14b Genesee shale	17′ to 25′
		14a Tully limestone	absent
b Mesodevonic period	*b* Middle Devonic group	*b* Middle Devonic group	
		13 Erian subgroup	
		13b Hamilton beds	76′
		13a Marcellus shale	211′
		12 Ulsterian subgroup	
		12c Onondaga limestone	108′ to
		(including Corniferous)	250′ ?
		12b Schoharie grit	absent
		12a Esopus grit	absent
a Paleodevonic period	*a* Lower Devonic group	*a* Lower Devonic group	
		11 Oriskanian subgroup	
		11a Oriskany beds	thin streaks of sandstone
		10 Helderbergian subgroup	
		10d Kingston beds (upper shaly)	absent
		10c Becraft limestone (upper Pentamerus)	absent

		10b New Scotland beds (Delthyris shaly)	absent
		10a Coeymans limestone (Lower Pentamerus)	absent
3 Siluric era	3 Siluric series	9 Cayugan group	
c Neosiluric period	*c* Upper Siluric group	9c Manlius limestone	7′ to 8′
		9b Rondout waterlime	60′
		9a Salina beds	386′
b Mesosiluric period	*b* Middle Siluric group	8 Niagaran group	
		8d Guelph dolomite	absent?
		8c Lockport limestone (Niagara limestone)	200′ to 247′
		8b Rochester shale (Niagara shale)	70′ to 80′
		8a Clinton beds	23′ to 40′
a Paleosiluric period	*a* Lower Siluric group	7 Oswegan group	
		7b Medina sandstone	1266′±
		7a Oswego sandstone, Oneida conglomerate or Shawangunk grit	75′±
2 Ordovicic era	2 Ordovicic series		
c Neordovicic period	*c* Upper Ordovicic group	6 Cincinnatian group	
		6c [Richmond beds] absent	
		6b Lorraine beds 6a Utica shale	630′
b Mesordovicic period	*b* Middle Ordovicic group	5 Mohawkian group	
		5c Trenton limestone 5b Black river limestone	680′ to 720′
		5a Lowville limestone (=Birdseye limestone)	absent?
a Paleordovicic period	*a* Lower Ordovicic group	4 Canadian group	
		4b Chazy limestone	absent?
1 Cambric era	1 Cambric series	4a Beekmantown limestone (=Calciferous sandstone)	10′ to 110′
c Neocambric period	*c* Upper Cambric group	3 Potsdamian group 3a Potsdam sandstone and limestone	
b Mesocambric period	*b* Middle Cambric group	2 [Acadian]	absent
a Paleocambric period	*a* Lower Cambric group	1 Georgian group	absent
		1a Shales and limestones of Troy and Washington co. N. Y.	

Geologic map

A few words, descriptive of the accompanying geologic map may be added.

The topography is indicated chiefly by contour lines. These lines are 20 feet apart, and each connects the points which have the same elevation above sealevel. Thus wherever the 300 foot contour line occurs, every point along that line is supposed to be 300 feet above sealevel. The level of Lake Ontario is 247 feet above the sea; therefore the hight of any point above Lake Ontario can be calculated from the contours. Where the contours are close together, the slope of the country is steep; where far apart, it is gentle.

The various color patterns indicate what geologic formations would be shown on the surface of any given area, if the drift covering were removed. The beds of this region all dip gently southward; and, as we proceed northward, the lower beds rise from beneath the covering of the higher. Where steep cliffs occur, as in the gorge of the river or at Lewiston or Queenston, the lower beds crop out beneath the upper ones for only a very short space; hence they appear on the map as narrow color bands only. The character of the outcrops in the buried St Davids channel is only approximately delineated, to the extent indicated by well borings. It is probably much more irregular than is shown.

The outlines of the edges of the various beds from Lewiston eastward are taken from a map by G. K. Gilbert, the man who more than any other is identified with geologic studies at Niagara. The outcrops of the Onondaga and waterlime beds are taken from a map by Prof. I. P. Bishop. For the other outlines the author is responsible.

A few statistics[1]

Hight of American falls, Oct. 4, 1842	167.7	feet
" Horseshoe falls, "	[2]158.5	"
Mean total recession of American falls between 1842 and 1890	30.75	"

[1] Chiefly from the annual reports of the commissioners of the state reservation.

[2] The hights vary from 4 to 20 feet with the elevation of the water in the river below the falls.

Mean annual recession of American falls between 1842 and 1890	.64	feet
Mean total recession of Horseshoe falls between 1842 and 1890	104.51	"
Mean annual recession of Horseshoe falls between 1842 and 1890	2.18	"
Length of crest line of American falls in 1842	1080	"
in 1890	1060	"
" Horseshoe falls		
in 1842	2260	"
in 1890	3010	"
Total area of rock surface which has disappeared at the American falls between 1842 and 1890	32,900	sq. ft
or	.755	acres
Total area of rock surface which has disappeared at Horseshoe falls between 1842 and 1890	275,400	sq. ft
or	6.32	acres

These changes are graphically shown in the successive crest lines of the Horseshoe falls, given in fig. 19, p. 81.

Volume of water passing over the falls each minute[1]	22,440,000	cu. ft
or	1,402,500,000	pounds
or more than	7,000,000	tons

Depth of water in the channel of Niagara river below the falls[2]: (*see* fig. 18)

At foot of Horseshoe falls (center)	150 to 200	feet
Upper Great gorge, from the falls to the beginning of the Whirlpool rapids (from soundings)	160 to 190	"
Whirlpool rapids	35	"
Whirlpool	150	"
Outlet of whirlpool	50	"
Opposite Wintergreen flat	35	"
Below Foster's flats	70	"

[1]Blackwell, Am. jour. sci. 1844, 46 : 67.
[2]Estimated by Gilbert. Am. geol. 1896, 18 : 232-33 and elsewhere.

Width of Niagara gorge[1] (approximate):

Opposite the extreme west end of Goat island, and just in front of the Horseshoe falls	1250	feet
Opposite the center of the American fall	1700	"
Opposite inclined railway	1350	"
Between carriage and railroad bridges, narrowest point midway between the two	1000–1350	"
Just south of railroad bridges	950	"
Gorge of the whirlpool rapids	700–750	"
100 rods south of south side of whirlpool	1200	"
Same at water line	850	"
Inlet to whirlpool	1000	"
Same at water line	550	"
Outlet of whirlpool	900	"
Same at water line	450	"
South of Ongiara park	1300	"
Just south of Wintergreen flat	1600	"
River opposite Foster's flats (bottom)	300	"
Just south of Foster's flats (top)	1700	"
North of Devil's hole	1000	"
At the tunnel on the New York Central railroad (plate 12)	1300	"
Average width below Lewiston	2000	"

[1]Chiefly after Taylor. Bul. geol. soc. Am. 9 : 61-65. Top width is given unless otherwise stated.

Plate 3

The Niagara escarpment above Lewiston (inface of the Niagara cuesta). The lower plain (Ontario lowland) with Lewiston is seen on the left. The sandspit of the Iroquois beach is also shown. R. W. & O. railroad track in the foreground

Chapter 1

PHYSICAL GEOGRAPHY OF THE NIAGARA REGION

The physical geography of the Niagara region is of a relatively simple type, its main topographic features being readily interpreted. Unfortunately no very satisfactory birdseye view of the entire

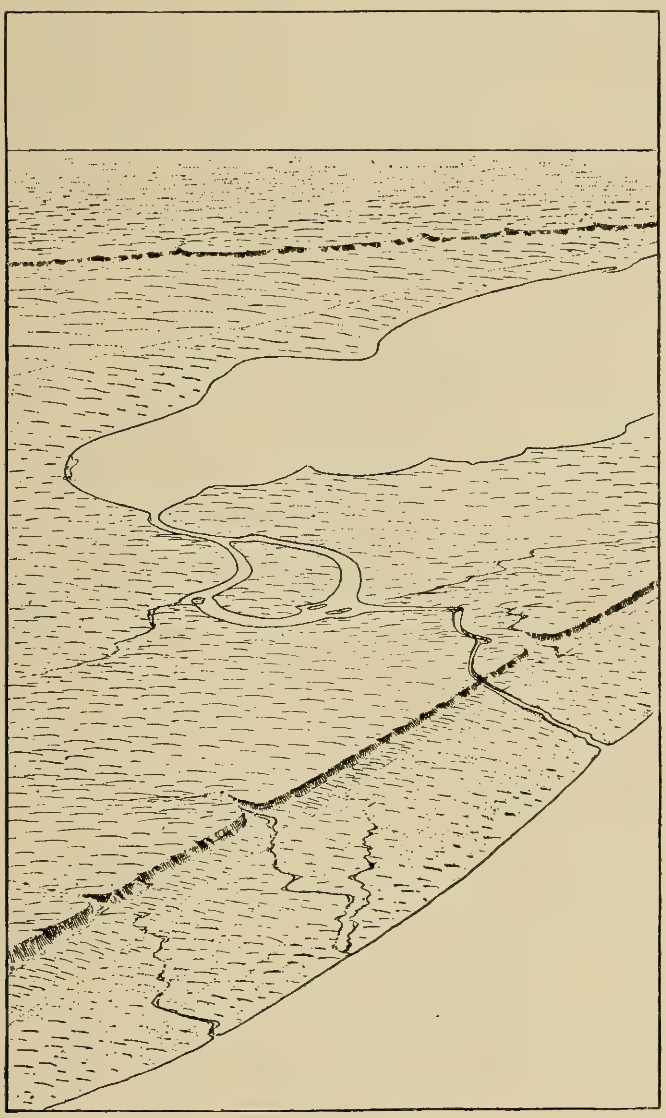

Fig. 2 Birdseye view of the Niagara region. (After Gilbert) The Niagara escarpment is shown in the foreground, with the lower plain sloping to Lake Ontario. The third upland belt is shown in the distance beyond Lake Erie. The second escarpment immediately north of Lake Erie, is not shown.

region can be obtained from any of the elevated points of the district; for the chief features are delineated on a scale too vast to be visible from a single vantage point. The best available spot from which a comprehensive view may be obtained is the summit of

Brock's monument, which commands the hights above Queenston, on the Canadian side of the river. Looking northward from this elevation, the observer sees an almost level plain, cut only by the winding lower Niagara, stretching from the foot of a pronounced and often precipitous escarpment to the shores of Lake Ontario, 7 miles away. Ordinarily the distant northern shore of the lake is not readily recognized by the unaided eye, though on clear days a faint streak of land may be seen between sky and water on the distant horizon. A good field glass however will generally disclose the opposite shore, and the much eroded cliffs of Scarborough. Far beyond these, fully a hundred miles to the north of the observer, the crystalline rocks of the Laurentide mountains rise from beneath their covering of Paleozoic strata, as formerly they rose above the waters of the Paleozoic sea. These ancient Canadian highlands, together with the Adirondack mountains of New York, and the old crystalline regions of the Appalachians, constitute the chief visible remnants of the old pre-Cambric North American continent. The erosion of these ancient lands has furnished much of the material from which beds of later date in this region were derived. Some of these beds may be seen in the sections cut by the rivers through the deposits in comparatively recent times, and no more instructive example than the gorge of the Niagara need be cited.

In the banks of the lower Niagara gorge may be seen the cut edges of the red shales and sandstones of the Medina group, the brilliant color of which is in striking contrast with the greenish blue of the water, and the darker green of the foliage which fringes its borders. The plain above is dotted with farms, orchards and hamlets, and is one of the richest agricultural and fruit districts of the country. In the foreground, on opposite banks of the river, lie the sister towns of Queenston and Lewiston, former rival guardians of the head of navigation of the lower Niagara, but now for the second time joined by bands of steel across the intervening gulf. Farther down the stream Niagara-on-the-Lake and Youngstown crown respectively the left and right bank of the river. These four towns of the lower Niagara, hold daily communication by ferry, steamboat or electric railway; the last and the steam railway keep-

ing them in touch with the cities of the upper Niagara and the world at large. This office is also performed by the well appointed steamboats which ply the lower Niagara, and carry passengers across Lake Ontario, to and from Toronto, the capital and metropolis of the province of Ontario. As these steamers enter or leave the Niagara river, they pass Forts Massassauga and Niagara which stand guard on opposite shores at the mouth of the river. The latter fort was established in 1678, and is rich in historic associations, while the Canadian fort is the modern successor of old Fort George, which was destroyed during the war of 1812.

When the observer on the Brock monument turns to the west or to the east, he sees the escarpment on which he stands, and the plain at its foot stretching in either direction beyond his field of view. The continuity of the escarpment is broken at intervals by ravines or gorges which dissect it, the most pronounced of these being the Niagara gorge in the immediate foreground. Westward from Queenston the escarpment is practically continuous for more than 3 miles, when, at the little town of St Davids, it is seen to recede abruptly, and a gap over a mile in width intervenes, beyond which it continues in force, with only minor interruptions, to Hamilton (Ont.), 40 miles west of the Niagara river. The gap at St Davids marks an ancient valley or gorge cut into the upland plateau which terminates at the escarpment. This old valley is traceable southeastward as far as the whirlpool, in the formation of which it has played a prominent part. It is filled throughout its greater extent by sand and clay, into which modern streams have cut gullies of greater or less magnitude.

Beyond St Davids, the escarpment, though indented by numerous streams, is as stated, continuous to Hamilton (Ont.). Here a larger and more pronounced interruption occurs, the escarpment being breached by a broad and deep channel, locally known as the Dundas valley. This ancient channel, with an average width of 2 miles or more, is traceable westward for a number of miles, when it becomes obliterated by drift deposits. Beyond the breach made by the Dundas valley, the escarpment continues in force, its direction however having changed to west of north, or nearly at right angles to its direc-

tion south of Lake Ontario. The eastern face of the Indian peninsula between Georgian bay and Lake Huron and the bold bluff of Cabot's head mark the northward extent of this escarpment, which, after an interruption by a broad transverse channel, is farther traceable in the northern slope of the Manitoulin islands. Eastward the escarpment continues to the vicinity of Lockport, where its continuity is interrupted by two pronounced gulfs, through one of which the Erie canal descends to the lowland of Lake Ontario. Beyond Lockport the escarpment becomes less pronounced; at first it separates into several minor steps or terraces and later it is replaced by a more or less continuous and gentle slope. Beyond the Genesee river it is no longer distinguishable, the surface of the country ascending gently and uniformly from Lake Ontario southward.

Turning now toward the south, the observer sees a second plain extending from the edge of the Niagara escarpment to where its continuity is blended with the horizon. This plain is not as uniform as the Ontario plain, which is fully 200 feet below it, and it is sharply divided by the Niagara gorge, from its northern edge at the escarpment to where, in the distance, a cloud of spray marks the location of the great cataracts. In the walls of the gorge can be seen the cut edges of the strata which enter into the structure of this higher plain, and attentive observation will reveal the fact, that the uppermost of these is a firm-looking limestone bed, which increases perceptibly in thickness toward the north. This thickening of the capping limestone bed, whose upper surface is essentially level, brings out a fact not otherwise readily noticed, namely that the strata all have a gentle inclination or dip to the south. The surface of the upper plain, aside from minor, mainly local irregularities, is essentially level, scarcely rising above the 600 foot contour line. This is the elevation, above the sea, of the base of Brock's monument, and it is the average elevation of the plain in the vicinity of Buffalo, the location of which, 20 miles to the south, is indicated by a perpetual cloud of smoke above the horizon.[1]

[1] A very satisfactory view of the level character of this plain is obtained during a ride by rail from Niagara Falls to Lockport, and thence by train or electric car to Buffalo.

For many miles to the east and west of the Niagara river the plain does not change perceptibly in elevation. Nevertheless, there is a gradual eastward descent, till, on the Genesee river, the surface of the plain, where not modified by superficial deposits, is fully a hundred feet lower than at Niagara. Westward the plain rises gradually, its elevation near Hamilton averaging 500 feet above Lake Ontario, or considerably more than 700 feet above the sea.

Owing to the southward inclination of the strata of this region, the limestone bed which forms the capping rock at the escarpment, eventually passes below the level of the plain, having previously increased in thickness to over 200 feet. The disappearance of the limestone as a surface rock occurs near the northern end of Grand island, as shown by the accompanying geologic map, and from this point southward the surface rock is formed by the soft gypsiferous and salt-bearing shales of the Salina group, which overlie the limestone and in turn pass below the higher strata in Buffalo, where beds of limestone again become the surface rock. Throughout the area where the shales form the surface rock, the plain is deeply excavated on both sides of the Niagara river, a longitudinal east and west valley, now largely filled by surface accumulations of sand and gravel, being revealed by borings. Tonawanda creek occupies this valley on the east, though flowing on drift, considerably above its floor, and Chippewa creek occupies it in part on the west of the Niagara river. This valley, as will be shown later, can be traced westward into Canada and eastward to where it joins the Mohawk valley, with which it forms the great avenue of communication across the state of New York. The northern boundary of the Tonawanda and Chippewa valleys is formed by a limestone cliff similar to, though less pronounced than, the Niagara escarpment. This cliff, generally known as the second limestone terrace of western New York (the Niagara escarpment being the first), is formed by the upper Siluric limestones (Waterlime and Manlius limestone) and the Onondaga limestone of the Devonic series. The latter is a very durable rock and hence it forms a very resistant capping stone. This escarpment is scarcely visible at Black Rock, where it is crossed by the Niagara river, for here it is low, and, in addition, extensive drift

accumulations have obliterated its topographic relief. Eastward and westward however it becomes prominent. A drive along Main street from Buffalo to Akron at the Erie county line will reveal the fact that it gradually increases in hight and boldness, till at the latter place it rises nearly a hundred feet above the Tonawanda valley, which itself is drift filled to a not inconsiderable extent. If we trace this escarpment into eastern New York, we find it progressively increasing in hight, owing to the interpolation, between the Manlius and Onondaga limestones, of the thick beds of the Helderbergian series, which, with the other lower Devonic beds, are entirely absent in the Niagara region, where their place is marked by an unconformity. (*See* figs.1 and 21-24)

If the observer changes his position to some elevated point near Buffalo, he may note that the plain which extends southward from the edge of the second escarpment, presents again a scarcely modified and almost level surface, which south of Buffalo gently descends to a third lowland, that of Buffalo creek and Lake Erie. Like the other lowlands, this one is carved out of soft rocks (Marcellus and Hamilton shales) and has subsequently been filled to some extent by drift deposits. This has been proved by borings which show that the bedrock in the valley of Buffalo creek is 83 feet below the surface of Lake Erie.[1] There are other excellent reasons for believing that the western end of this lowland, now occupied by Lake Erie, was once considerably lower than at present.

On the south the Erie lowland is defined by a range of hills, the northern edge of the great Allegany plateau, which forms the highlands of southern New York and northern Pennsylvania. There are no very pronounced declivities in the northern edge of this plateau in the Lake Erie region, owing no doubt to the relatively uniform character of the rocks composing it, there being no resistant capping bed of sufficient magnitude to produce an escarpment. Farther east, however, owing to the increasing thickness of the beds and their more resistant character, a prominent escarpment is developed, which near the Hudson unites with the escarpment of the lower series, and with it constitutes the prominent Hel-

[1] Pohlman. Life history of Niagara. 1888. p. 4.

derberg range, which culminates in southeastern New York in the high plateau of the Catskills. The Allegany plateau is everywhere much dissected by streams whose gorges have made the scenery of southern New York famous.

We have now seen that the topographic features of the Niagara district are arranged in a series of six east and west extending belts of alternating lowlands and terraciform elevations. The lowlands are the Ontario, Tonawanda-Chippewa, and Erie, the uplands are defined by the Niagara escarpment, the Onondaga escarpment and the hills of southern New York which constitute the northern edge of the Allegany plateau. The northern boundary of this belted country is formed by the old Canadian highlands.

We must now briefly consider the various strata of which the area under consideration is constructed, their origin, and the manner in which the topographic features of this region were produced. A brief review of the table of Paleozoic strata, given on pages 20 and 21, will be helpful to an understanding of the succeeding pages.

Development of the Paleozoic coastal plain

The Laurentian old-land is composed of rocks older than the Cambric period of the earth's history. These are largely of igneous origin, and such as were originally sediments have generally suffered much alteration through heat, pressure and other causes, and in most cases have assumed a more or less crystalline character. Though many of these pre-Cambric rocks may show apparent stratification, the present attitude of the beds does not often bear a close relation to their original condition. Indeed, these ancient rocks are generally much disturbed, their beds folded and flexed, and their laminae much contorted. Nor do the layers of the pre-Cambric rocks bear any normal relation to those of later date, the two series being wholly discordant with each other. The older beds are much worn, vast portions of the ancient folds having been swept away by erosion, and on the truncated edges of the remaining portions the newer strata were deposited in an essentially horizontal position. This *unconformity* of relation between the newer and older strata is a marked feature wherever the two series are ex-

hibited in contact with each other. Generally the older rocks have been worn down to an undulating plain (or peneplain), and the succeeding beds made from the fragments which were worn from the old land.

In the area under consideration, the ancient erosion surface of pre-Cambric rocks was overspread by a deposit of sand and occasionally gravel, which commonly possesses characteristics pointing to a very local origin. Thus the pebbles found in the lowest layers of the covering sands, i. e. the Potsdam sandstone, are sometimes of the same lithic character as the crystalline rocks near by. The Potsdam sandstone is a shallow-water rock, and during its accumulation a progressive subsidence of the sea floor took place, thus allowing the deposition of beds of considerable thickness. This subsidence brought with it a northward migration of the shore line of the sea, so that the region of the former coast line gradually became more remote from the shore. As a consequence, land-derived material became less abundant in this off-shore district, being deposited mainly along the new coast line, while farther out to sea calcareous deposits, resulting in part from the shells of organisms, became relatively more abundant. A profile through the strata of this region, such as would be obtained in a well or shaft sunk to the crystalline floor, would show a progressive decrease in the land-derived, or terrigenous material from the Potsdam sandstone upward to the top of the Trenton limestone, and a correspondingly progressive increase in the amount of calcareous matter. This indicates a sustained subsidence of the sea floor, and hence a migration of the shore with its attendant terrigenous deposit. It will also be seen that the lithic character of any particular formation is not the same throughout its extent, but that the local characteristics, or *facies*, show considerable variation. Close to the shore each formation would present a terrigenous character, i. e. would show gravelly, sandy or clayey facies, while away from shore each formation would pass into its calcareous facies, which would increase in purity with the increase in distance from the source of supply of terrigenous sediment. Thus the Potsdam formation has calcareous as well as sandy facies, with facies of intermediate type connecting them.

The Utica shales and the arenaceous Lorraine shales which follow on the Trenton limestones show a return of land-derived deposits due probably to a shoaling of the water. This may have been caused by an upward movement of the sea bottom or by a partial withdrawal of the water into deepening oceanic basins. Some abrupt change is indicated by the sudden transition from limestone to black shale. Another abrupt change occurred at the close of the Ordovicic era, as indicated by the marked contrast between the Lorraine shales and the Oneida and Medina beds which immediately succeed them.

The Siluric deposits of this region began as shallow water accumulations, the lowest bed being the Oswego sandstone, which farther east, is replaced by the conglomerates of Oneida county and the Shawangunk range. The marls and shales of the Medina series succeed these sandstones with an aggregate thickness exceeding 1100 feet. A heavy stratum of gray quartzose sandstone, varying in thickness up to 25 or 30 feet, separates, in the Niagara region, the lower from the upper Medina shales and sandstones, which have an approximate thickness of 100 feet. The Clinton shales and heavy limestones follow on the Medina, with a thickness averaging 30 feet. The Rochester shales, with a thickness of 60 to 70 feet, follow the Clinton limestones and are in turn succeeded by the Lockport limestone, whose average thickness, obtained from well records, approximates 250 feet in this region. The Salina shales succeeding the Niagara beds (Rochester shales and Lockport limestone) have an aggregate thickness of less than 400 feet, and are followed by the Waterlime and the Manlius limestone, the former averaging 50 feet in thickness, the latter from 7 to 8 feet. The lowest Devonic beds are absent in this region, the Onondaga limestone resting directly on the Manlius beds, there being, as before noted, an important though not very pronounced unconformity between the two. A glance at the geologic map of this region will reveal the fact that the lower strata rise from under the covering newer beds on the north, and occupy a belt of country of greater or less width according to the thickness of the beds. Where they come to an end, the next lower beds make their appearance. The discontinuation of the higher

beds northward is due to a thinning out of the exposed portion of the strata, as can be readily seen in the Lockport limestone bed, which is less than 30 feet thick at Lewiston, but more than 80 feet at the falls, increasing in thickness southward to 250 feet or more. Where, however, the strata are not exposed on the surface, i. e. where they are only shown in sections under cover of the overlying rock, no such thinning is seen. This may be observed in the case of the Clinton beds and the upper Medina sandstones. In some cases these beds are seen to even thin southward, as proved by borings. The thinning of these strata does not, as is often assumed, mark the original thinning of the beds toward the shore on the north, but is evidently due to erosion. A brief résumé of the origin of the various strata will make this clear.

The Medina sandstone is an ancient shore and shallow water deposit, as will be more fully pointed out in chapter 3. The sands and gravels, which with some finer muds, make up this rock, are all derived from some preexisting land. The only source of supply was the old Laurentian land on the north and the Appalachian old-land on the south. It is true that, owing to the elevation at the beginning of Siluric time, some of the pre-Siluric stratified rocks may have been raised above the sealevel and added to the old-land, and that part of the Medina sands may have been derived from these. Even then the largest amount of detritus was probably derived from the crystalline old-lands, the progressive accumulation of 1200 feet of Medina rock marking a corresponding subsidence and a concomitant encroachment of the seashore of the Medina sea on the old-land. Thus the Medina deposits gradually overlapped the Ordovicic and Cambric deposits and probably eventually came to rest entirely on the crystalline pre-Cambric rocks. Continued subsidence, at least in the Niagara region, produced the purification of the water, so that eventually the limestones of the Clinton epoch could be formed in a region remote from that in which terrigenous material was accumulating. This was likewise true of the Lockport limestone, which was deposited after an interval, during which the calcareous shales separating the two limestone series accumulated. While

these deposits, particularly the limestones, point to a considerable distance from the shore line, we are by no means at liberty to assume that no shore formations accumulated during this period. In fact, it would be difficult to understand the non-accumulation of terrigenous material along the shores of any land during any period of the earth's history unless such land was without even moderate relief. As will be shown in chapter 3 there are reasons for supposing that a considerable land barrier existed in the north as well as the east and southeast, and thus we may assume that shore deposits of terrigenous material were formed while the limestones were accumulating in the clearer waters. That the shores of this period did not consist of Medina sandstone is indicated by the absence of any such material in the shales of either the Clinton or Niagara series. It is highly probable that the shore was still formed by the old crystalline highlands, and that the accumulating Clinton and Niagara sediments overlapped and completely buried the Medina beds. The limestones are chiefly fragmental in origin, being composed of calcareous and magnesian sands. These, as will be shown later, were largely derived from the destruction of coral reefs and shells growing in the immediate neighborhood. They indicate shallow water, a conclusion emphasized by the occurrence of well marked cross-bedding structure in some of the beds of limestone. We may assume a gradual passage from pure calcareous beds to beds consisting more and more of terrigenous detritus as we approach the old shore line, where quartz sands probably constituted the chief material of the deposits.

We may obtain an approximate indication of the former extent of these strata if an attempt be made to restore the portions which must have been removed by erosion. We may consider the Clinton and Niagara as a unit, assuming that near the old shore their beds were practicably indistinguishable. The average dip of the strata of this region is 25 feet to the mile (a moderate estimate, as the dip ranges up to 40 feet), and the base of the Clinton-Niagara is approximately 400 feet above sea level. Continuing this dip northward for a hundred miles to where the present borders of the oldland are exposed, the base of this group would have risen 2900 feet

above the sea, an elevation sufficient to overtop the highest peak of the present Laurentides; for, according to Logan, "in the country between the Ottawa and Lake Huron the highest summits do not appear to exceed 1500 or 1700 feet, though one . . . probably attains 2300 feet".[1] We assume of course with good reason that the Laurentides at that period were much higher than now, for they must have suffered enormous erosion during the long interval since the close of Siluric time.[2]

Since the deposition of these Siluric strata the region under consideration has suffered an enormous amount of denudation, having been brought to the condition of a low nearly level tract or *peneplain*, but little above sea level, not once, but probably a number of times, separated by periods of elevation and at least one of sub-

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[1] Logan. Geol. Canada. 1863. p. 5.

[2] The Niagara beds of Lake Temiscaming, in the great pre-Cambric area of Canada and 150 miles distant from the nearest beds of the same age, are of interest in this connection. They occupy an area about 300 miles due north of Lewiston and on the north side of the present Laurentide chain. According to Logan they do not properly belong to the former extension of the Niagara beds of the region under consideration, but rather to the Hudson bay area on the north. They are of interest however as showing the great former extent of these formations. They lie unconformably on the pre-Cambric rocks, and the basal members are generally sandstones and often conglomerates "containing large pebbles, fragments, and frequently huge boulders of the subjacent rock" (Logan, p. 335). The thickness of the formation here is estimated at between 300 and 500 feet. The Ordovicic and Cambric strata are absent, showing a progressive encroachment of the sea on the old-land, and a consequent overlapping of the strata. Outliers of earlier strata are found in more southern portions of Canada, resting on the pre-Cambric surface, and many of these indicate a progressive overlapping of later over earlier beds. Lawson holds that this indicates, that most of the Canadian old-land was covered by the early Paleozoic strata, and that erosion since Paleozoic time has resulted in simply removing these overlying rocks. (Bul. geol. soc. Am. 1 : 169 et seq.) He holds that comparatively little erosion of the old-land has occurred since Paleozoic time, the present surface being essentially pre-Cambric and only revealed by stripping of the overlying rocks. It is not improbable however that some of these distant outliers may have been preserved during the extensive denudation of the old-land, by having been faulted down previously in a manner well known to have occurred in the Scandinavian old-lands, a solution suggested to me by my friend, A. W. G. Wilson, of Harvard university.

sidence. The present surface of the Niagara plateau is therefore not to be considered as identical with the old surface of deposition, but as due to prolonged peneplanation, or erosion to near sealevel, completed probably toward the close of Mesozoic or the beginning of Cenozoic time. The following diagram (fig. 3) will illustrate the relation between the strata and the surface of the land at 1) the close of Siluric time, 2) late Mesozoic or early Cenozoic time, after the completion of the last cycle of erosion and the reduction of the land to peneplain condition, and 3) the present surface.

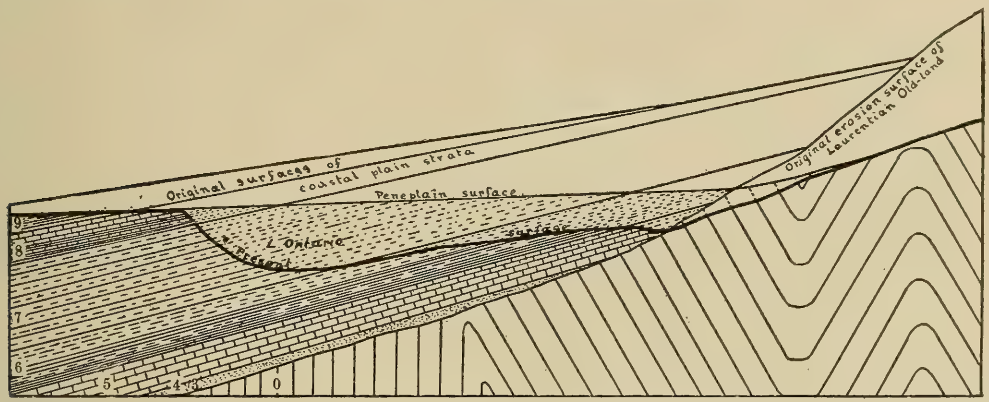

Fig. 3 Diagram of ancient Paleozoic coastal plain, and its relation to the Mesozoic peneplain surface and the present land surface. The numbering of the beds corresponds to that of the table.

Between the close of the Siluric and beginning of Mesozoic time a long period intervened, during which this region was at first a land surface, suffering considerable erosion, but later was resubmerged, and covered with extensive deposits of Devonic limestones, shales and sandstones. The final emergence took place at the close of Paleozoic time, the succeeding Mesozoic time being in this region probably an uninterrupted period of erosion, during which the land suffered the combined attacks of the atmosphere and of running water.

Development of the drainage features

The water which falls as rain or snow on the land either evaporates, runs off on the surface, or sinks into the ground, where it constitutes the ground water. That which evaporates, accomplishes little or no direct geologic work, but both the surface and underground waters are important geologic agents. If the surface on which the water falls is a perfectly smooth but inclined plain, the water will run off in the form of a thin sheet. A perfectly smooth

land surface is however unknown, and the run-off of the surface waters is always concentrated along certain lowest lines, thus constituting brooks, streams and rivers. While there may be numerous drainage lines of this type, they generally unite into a few master streams, the direction of whose flow is down the inclination of the surface of the land. Such streams are known as *consequent* streams, their direction of flow being consequent on the original slope of the surface.

When the strata of the Niagara region became a part of the dry land, from the relative lowering of the water level (which may have been due to rise of the land or to drawing off of water by the deepening of the oceanic basins), they formed a broad, essentially monotonous belt of country fringing the old-land on the north, i. e. a marginal coastal plain. The strata of this plain had a gentle southward inclination, a feature shared by the surface of the plain. Consequent streams quickly made their appearance on this plain, a number of them probably coming into existence almost simultaneously and running essentially parallel from the old-land, across the new coastal plain into the sea. These streams soon cut down into the coastal plain, carving channels for themselves and thus establishing definite lines of drainage. As the streams at first consisted entirely of the run-off of the moisture which fell on the plain and in the higher old-land portion, it is evident that, unless the rainfall was continuous, or unless extensive snow fields were present to supply water, these young streams must have fluctuated greatly in volume of water, and at intervals become entirely dry. This condition continued till the valleys, cut by these streams of run-off water, had become sufficiently deep to reach the level of the underground water, when the supply, augmented by springs, became much more constant. Thus in course of time large valleys, supplied with large rivers, came into existence. Meanwhile the sides of the river valleys were attacked by the atmosphere, and degradation of the cliffs cut by the stream resulted.

As long as a river is narrow and vigorously undercuts its banks, the latter will be steep, and the river channel will have the character of a gorge. This generally continues as long as the river is cutting

Plate 4

American and Luna falls from below, with limestone fragments fallen from the cliff above (Copyright by Underwood & Underwood, New York)

downward, i. e. till the grade of the river bottom is a very gentle one, when lateral swinging widens the gorge by undercutting the banks, and atmospheric degradation quickly destroys the steep cliffs which the river does not keep perpendicular.

During the process of drainage development, numerous side streams come into existence, which join the main stream as branches. These begin as gullies formed by the rainwater running over the sides of the banks into the main stream. A slight depression in the surface, or a difference in the character of the material composing the banks, may determine the location of such a gully, but, once determined, it will become the cause of its own farther growth. For the existence of this gully will determine the direction of flow of succeeding surface waters, and so in the course of time the gully will become longer and longer by headward gnawing, till finally a channel of considerable magnitude is produced. Streams of this type are known as *subsequent* streams, and they very generally have a direction varying from a moderately acute to nearly a right angle with reference to the main or consequent stream.

As the dissection of the Niagara coastal plain continued, the higher portions of the strata, i. e. those nearer the old-land, were slowly removed, and the beds lying beneath these were thus exposed. The latter strata were generally of a more destructible character than the overlying ones, and on this account great lowlands, parallel to the old shore line, or the line of strike of the strata, were worn in them by subsequent streams. The more resistant beds, meanwhile, favored the formation of more or less prominent cliffs or escarpments which faced the lowlands, and being undermined slowly retreated southward, thus increasing the width of the lowlands. These features are today repeated in the Niagara escarpment which faces the Ontario and Georgian bay lowlands, and the escarpments formed by the outcrops of the Ordovicic limestones farther north. The diagram, fig. 4, illustrates the probable condition during early Mesozoic time. The great master consequent streams indicated are: the Saginaw, the Dundas and the Genesee, flowing from the old-land on the northeast, southward or southwest-

ward into the Mesozoic interior sea. There were probably other consequent rivers, whose location may be in part indicated by some of the valleys now occupied by the Finger lakes of New York. Subsequent streams, flowing along the strike of the beds and capable of accomplishing much erosion by undermining the resistant capping beds of the escarpments, continued to widen the longitudinal (i. e. eastwest) lowland areas, while the transverse valleys of the consequent streams remained relatively narrow.

The topographic relief feature produced by this normal development of drainage on a young coastal plain consisting of alternating harder and softer strata, has been named a "cuesta",[1] and may be briefly defined as an upland belt of slightly inclined coastal plain strata, with a surface gently sloping toward the newer shore, and a steep escarpment, or *inface,* fronting a low belt, or *inner lowland,* which separates the cuesta from the old-land upon which its strata formerly lapped. The existence of the cuesta form is usually due to a more or less resistant stratum overlying a less resistant one, as, for example, the limestones overlying the upper Medina shales. The inface of the cuesta is continually pushed back by the undermining subsequent streams, aided by atmospheric attack, and thus the belt of low country, lying between the cuesta and the old-land, is continually widened, while during the same time the valley of the transverse consequent stream which carries out the drainage increases comparatively little in width. It must be remembered however that the lowland can never be deepened below the depth of the valley of the consequent stream which carries its waters through the breach in the cuesta.

While the main drainage of this region was undoubtedly southwestward by consequent streams, which flowed through the cuesta in gorges, and by subsequent streams flowing into the former, and occupying the inner lowlands, short streams, flowing toward the old-land, down the inface of the cuesta, were probably not uncommon. These streams began to gnaw gullies back from the inface

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[1] Davis, W. M. Science. 1897. New series. 5:362; *also* Textbook of physical geography. 1899. p. 133. Pronounced kwesta, a word of Spanish origin "used in New Mexico for low ridges of steep descent on one side and gentle slope on the other".

of the cuesta, and ultimately prolonged these gullies into gorges, and carried the drainage into the subsequent streams. Streams of this type, which have their representatives in all coastal plain regions, have been called *obsequent* streams,[1] their direction of flow being opposite to that of the consequent streams. The following diagram (fig. 4) illustrates this type of a stream and its relation to the subsequent and consequent streams. To this type of stream belongs the ancient St Davids gorge, as will be shown more fully in subsequent pages.

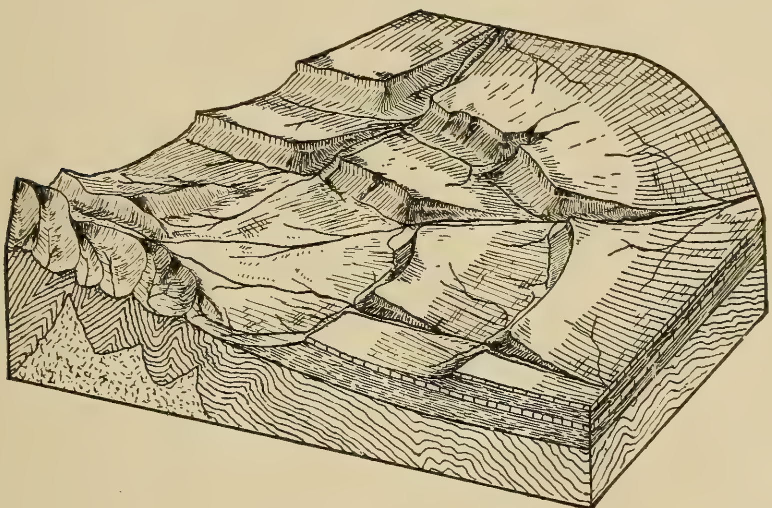

Fig. 4 Diagram of a portion of a dissected coastal plain, showing old-land on the left, and two cuestas with their accompanying inner lowlands. Three consequent streams have breached the cuestas, and subsequent streams from the lowlands join them. An obsequent stream is shown in the center of the outer cuesta.

If we assume that during the greater part of the Mesozoic era, the land in this region remained in a constant relation to the sea-level, it becomes apparent that the southward retreating infaces of the cuestas formed by the resistant members of the Paleozoic rocks, became lower and lower, as the southward inclination of the strata carried the resistant beds nearer and nearer to sealevel. Eventually the escarpment character of the infaces must have become obsolete, from the disappearance, beneath the erosion level, of the weaker lower strata, which permitted the undermining of the capping beds. When this occurred, the capping strata alone continued exposed to the action of the atmosphere, and, from a cliff character, their exposed ends were planed off to a wedge shape, thin-

[1] W. M. Davis

ning northward at a rate proportional to the dip of the beds. The ultimate result of all this erosion was the reduction of the land to a low peneplain, which did not rise much above the sealevel. Portions of this peneplain are today preserved in a scarcely altered condition, in the Niagara upland, the region about Buffalo and other localities. The slight change which these regions have subsequently undergone leads to the supposition that the peneplain was completed in comparatively recent geologic time, possibly at the beginning of the Tertiary era, or even more recently. This is also shown by the comparative narrowness of the valleys cut into the peneplain surface in preglacial times. The present altitude of this peneplain in the vicinity of the Niagara river is approximately 600 feet above sealevel, while southward it rises. There is however good presumptive evidence, some of which will be detailed later, that, during a period preceding the glacial epoch, the land in the north stood much higher than at present, so that the slope of the surface was southward. An accentuation of slope would cause a rejuvenation of the consequent streams, which, in the later stages of peneplanation, had practically ceased their work of erosion on account of the low gradient of the land. As a result of the renewal of erosive activity the early Mesozoic topography was in a large measure restored, but the inface of the Niagara cuesta, the top of which is now found in the Niagara escarpment, occupied in the restored topography a position considerably farther to the south than that characteristic of early Mesozoic time.

We may now examine more in detail the channels of the consequent streams which dissected this ancient coastal plain, and the extent of the inner lowlands drained by the subsequent streams tributary to them.

Dundas valley. The Dundas valley appears to have been the outlet for the master consequent stream of this region, the Dundas river. This valley, as before noted, breaches the escarpment at Hamilton (Ont.), near the extreme western end of Lake Ontario. The valley has been carefully described by Spencer, who considered it the pathway of the preglacial outlet of Lake Erie into Lake Ontario, the drainage of the Erie valley being in his opinion by a

river which followed the present course of the Grand river, above Cayuga, past Seneca and Ancaster into the western end of the Ontario valley. It is extremely doubtful that such a stream ever existed, certainly it is highly improbable that the Dundas valley owes its existence to any stream which flowed eastward or toward the old-land, for it is altogether too broad, and continues too uniformly to permit its being regarded as the valley of an obsequent stream. Moreover, its peculiar position at the elbow of the escarpment is most suggestive of a consequent origin, for we would expect the face of the cuesta to make a reentrant where the master stream gathers its converging tributaries and flows out through a great breach in the cuesta.

The Dundas valley is 5 miles wide at Hamilton but rapidly decreases in width to 2 or 2½ miles at the top, where the limestone forms decidedly sharp summit angles (Spencer). Its northern wall has been traced westward for 6 miles to Copetown, and its southern for 3½ miles to Ancaster. Beyond these points the valley is filled with drift which has been much dissected by modern streams. The axis of the gorge is about n 70° e, and the glacial scratches observed on the rock surfaces at its summit, with few exceptions, make angles of 30° or more with it (Spencer).

At Hamilton the bedrock was found to be absent to a depth of 227 feet below the surface of Lake Ontario. The well from which this record was obtained is about 1 mile distant from the southern side of the Dundas valley, which is here 5 miles wide. The total known depth of the canyon is, according to Spencer, 743 feet, but he calculates that it reaches 1000 feet near the center.[1] Along the northern shore of Lake Erie well records have shown the absence of drift to a considerable depth. Thus, according to Spencer, at Vienna, 100 miles due west of Buffalo, the drift is absent to a depth of 200 feet below the surface of Lake Erie, while at Port Stanley, 20 miles farther west, it is absent to a depth of 150 feet below the lake. At Detroit the drift is 130 feet deep. At St Marys on the northwest and Tilsonburg on the southeast of a line connecting

[1] Spencer. Pa. geol. sur. Q 4. p. 384–85.

Port Stanley with Dundas, Devonic limestones occur at a considerable elevation above Lake Erie (Spencer). Hence the southwestward continuation of the Dundas channel must be placed between

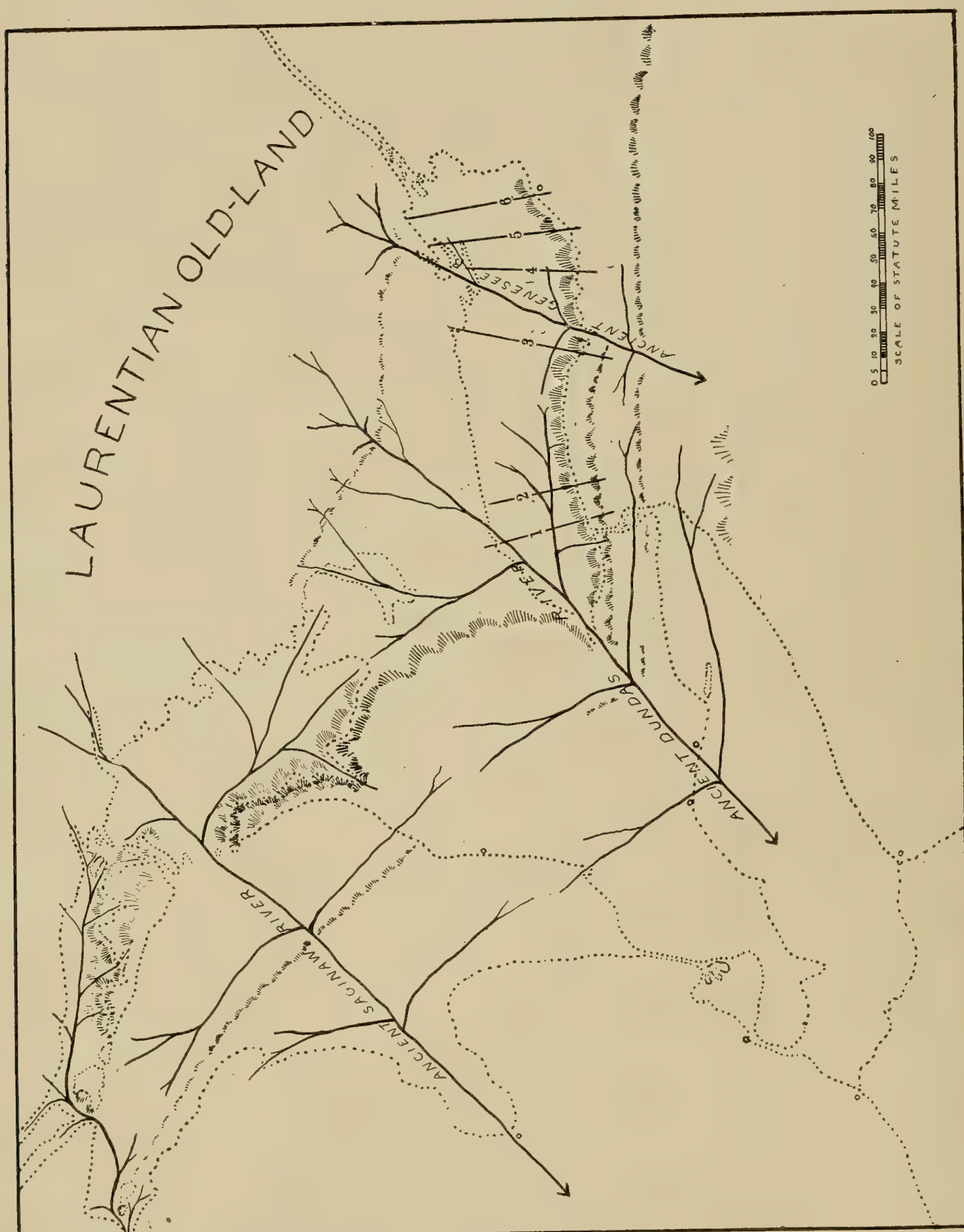

Fig. 5 Diagram showing type of drainage existing in Tertiary times in the Laurentian region,[1]

[1]These maps are intended merely to illustrate the *kind* of drainage, which it is believed existed in preglacial times in the Laurentian region. The ancient consequent streams are probably correctly located; yet it must be stated that the region between Hamilton and Port Stanley has not been sufficiently explored to make the course indicated certain. These consequents may have had a more indirect course, for if the country was worn down to peneplain condition, as appears to have been the case, these streams may have learned

these two points. On the southern shore of Lake Erie borings have revealed numerous deep channels. Thus the bottom of the ancient channel of the Cuyahoga river is reached, according to

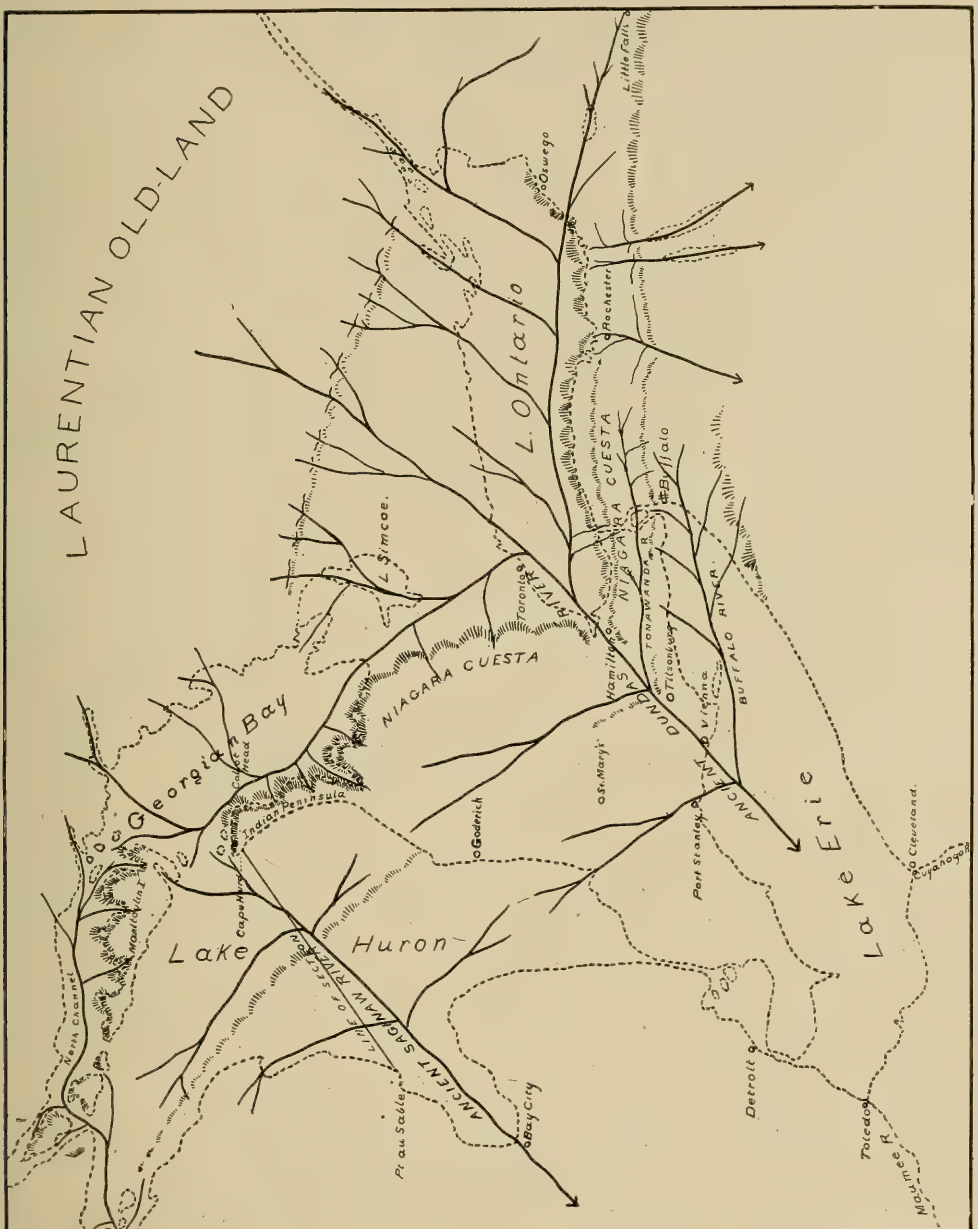

Fig. 6 A hypothetic later stage, showing adjustments which are suggested by existing relief features.

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to meander on this surface, the meandering course being retained on re-elevation. The depth of the bed rock at Port Stanley and Vienna, however suggests that a direct channel exists as shown on the map. The principal subsequents are probably located with approximate correctness, but the smaller branches are added without attempt at correctness. They were probably much more numerous than here shown.

Upham,[1] at a depth of more than 400 feet below Lake Erie. Whether this marks the former southward continuation of the preglacial Dundas river or whether that river turned more to the west, following in general the course of the present Maumee, must for the present remain unsettled. The Dundas undoubtedly became eventually tributary to the Mississippi.

Preglacial Saginaw river. The existence of an ancient river, flowing southwestward from the Canadian old-land across the valley of Lake Huron and the lower peninsula of Michigan, and finally becoming tributary to the ancient Mississippi, is indicated by the present character of the topography of that region. The Niagara cuesta is breached by a deep channel which now connects Georgian bay with Lake Huron, and which, north of Cove island, an outlier from the Indian peninsula, has been sounded to a depth of over 300 feet. This channel is in direct line with that of Saginaw bay, and, though this latter is at present very shallow, borings at Bay City show an absence of rock to a depth of at least 200 feet below the surface of the bay. At Alma (Mich.) the rock was shown to be absent to a depth of 350 feet below Lake Huron (Spencer); and, as this locality lies to the southwest of Saginaw bay and in line with the trend of its axis, we may assume that our preglacial Saginaw river was located here. Our limited knowledge of the preglacial topography of this region forbids tracing this channel beyond this point. Dr Spencer many years ago traced out this line of drainage, but he assumed that the river which occupied this channel, and which he has named Huronian, flowed northeastward to join that part of the ancient St Lawrence, or Laurentian river, which he supposed to have occupied Georgian bay.

Preglacial consequent Genesee river. Among the numerous consequent streams which flowed from the old-land southward or southwestward and which eventually became tributary to the preglacial Mississippi, probably through the ancient Ohio,[2] the pre-

[1] Bul. geol. soc. Am. 8: 7.

[2] Westgate, Lewis. Geographical development of the eastern part of the Mississippi drainage system. Am. geol. 1893. 11:245-60. The Ohio, according to Newberry, flows nearly throughout its entire course in a channel, the rock bottom of which is nowhere less than 150 feet below the present river. The rocks at the "falls of the Ohio" show that at that point the river is not following the ancient course.

glacial Genesee river is the only other that can be mentioned here. Though now flowing northward on account of the tilting of the land, we may assume that much of its valley was carved by a southward flowing stream, the bottom of which, as shown by borings, was considerably below the floor of the present river. Whether Irondequoit bay is a part of this ancient channel, or whether it marks the position of an obsequent stream, must remain for the present an open question. Soundings in Irondequoit bay show a depth of 70 feet, though the rock bottom is probably much deeper.

As soon as the consequent streams began cutting down their valleys again after the continental uplift which followed the period of peneplanation, the lateral subsequent streams began once more to open out broad lowlands in the weaker beds which now had become extensively exposed. These lowlands, in part now filled by drift deposits, are the Ontario and Georgian bay valleys, the latter continued in the North Passage, all carved out of the weak Medina and Lorraine shales; the Tonawanda-Chippewa valley, with the deeper portion of the Huron valley farther west, carved out of the soft shales of the Salina group; and the valley of Lake Erie cut out of the softer middle and upper Devonic shales. A few of these may be considered in greater detail.

Ontario valley. It is a well known fact that Lake Ontario is deeper in its eastern than its western part. In the following six cross-sections (fig.7), constructed from the lake survey charts, the greatest depths from west to east are 456, 528, 570, 738, 684 and 576 feet. The section showing the greatest depth is that from Pultneyville to Point Peter light, in the eastern third of the lake. As the present level of Lake Ontario is 247 feet above the sea, the deepest sounding recorded in these sections is 491 feet below present sealevel. From this point of greatest depth, the floor of the lake rises eastward, at first at the rate of 3 feet in the mile, and later at an average rate of 9 feet a mile. The valley appears to be continued south of the Adirondacks in New York along the present course of the Mohawk river, which flows at present several hundred feet above the rocky floor of the valley.[1] This floor ascends eastward, till at Littlefalls

[1] Carll. Pa. geol. sur. I^3:363.

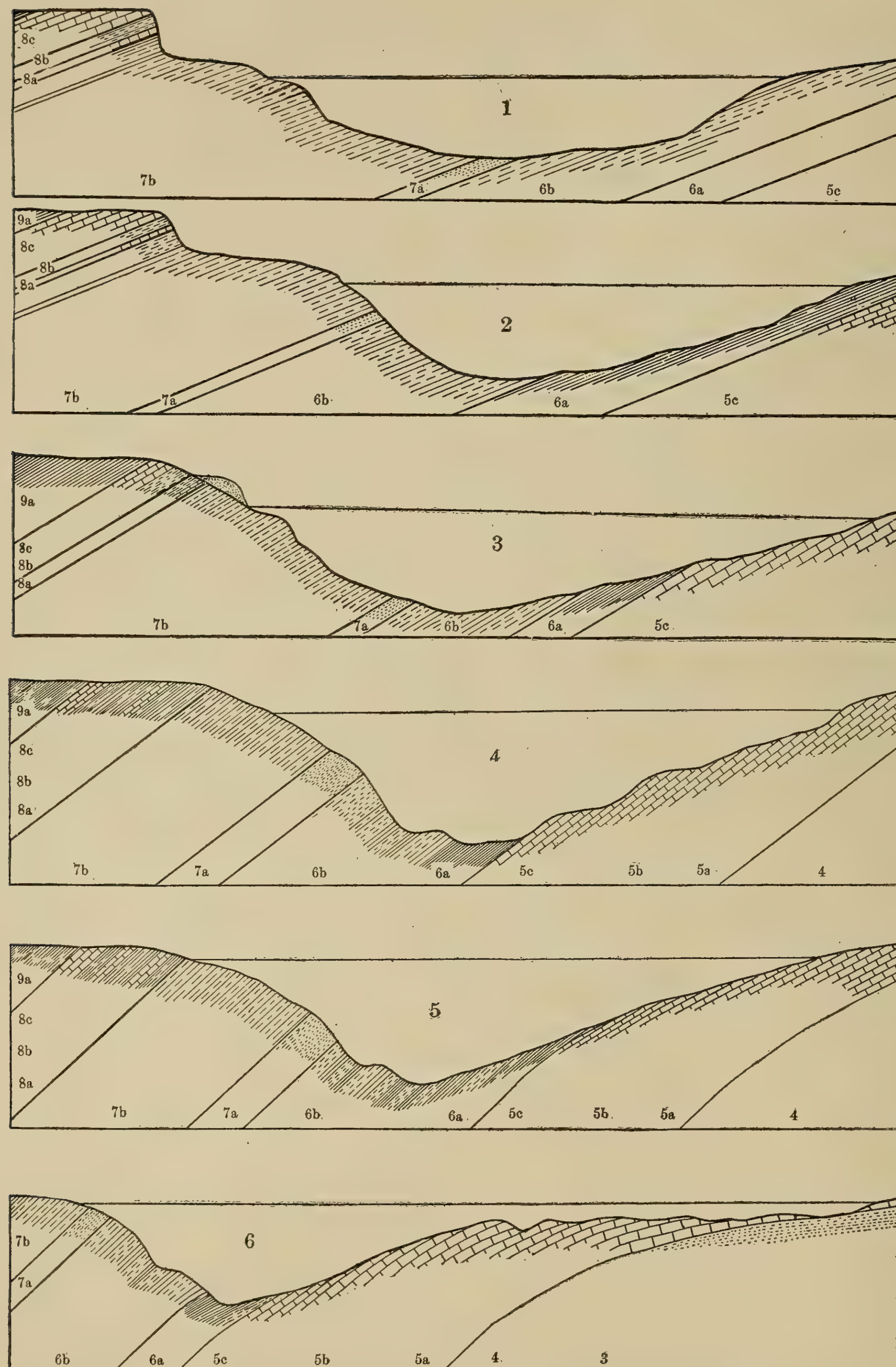

Fig. 7 Six cross-sections of Lake Ontario showing topography and geology. Vertical scale 1 inch = 1280 feet; horizontal scale 1 inch = 15¾ miles. Numbering of beds as in table; location of sections indicated in fig. 5. Section 1) E. of Niagara to E. of Pickering light. 2) Lockport to Darlington light. 3) West of Genesee to Presque Isle light. 4) Pultneyville to Point Peter. 5) West of Fair Haven light to False Buck light. 6) Oswego to Kingston.

the preglacial divide has an elevation of 440 feet above sealevel.[1] The following diagram (fig. 8) shows the present relation of the deepest part of the channel of Lake Ontario to sealevel, and the relation which would result by a tilting of the land back to its probable position in preglacial times. The last profile shows a continuous westward slope of the floor of the valley, steeper in the eastern portion, where the rocks are harder and the valley narrower, and more gentle in the western portion, where the softer rocks have allowed the opening of a broad lowland.

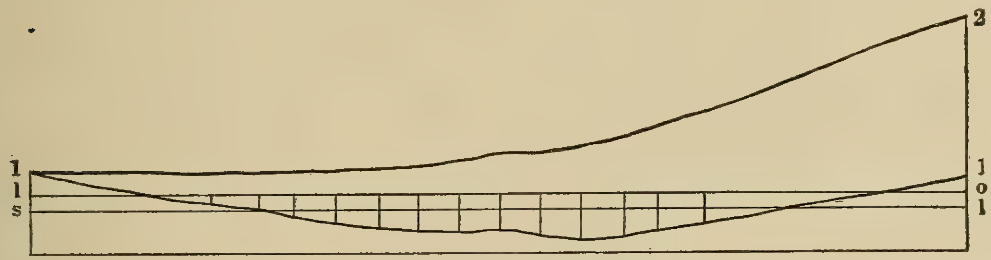

Fig. 8 Diagram showing the present deepest e–w channel of Lake Ontario along line 1–1, and its relation to sealevel s. l. and the level of Lake Ontario l. o. At 1, left side of diagram is represented the bottom of the channel at Vienna, 200 ft below level of Lake Erie or 370 ft above sealevel. At 1, right side, is the divide at Littlefalls 440 ft A. T. The line 1–2, is the line 1–1, but elevated on the east (right) so as to give a continuous westward drainage. Horizontal scale 1 inch = 100 miles. Vertical scale 1 inch = 4000 feet.

Numerous theories have been advanced to account for the deep basin of Lake Ontario. Spencer believed it to have been formed by an eastward flowing stream, the ancient Laurentian river, which received the Erian river as a tributary through the Dundas valley. The eastward continuation of this river Spencer believed to have been essentially along the course of the modern St Lawrence, the present great elevation of the rocky bed of this stream, above that of Lake Ontario, being explained by a warping of the land. Upham also believes that the basin is in part due to warping, but he considers it the valley of a westward flowing stream. Russell also holds this latter view; for he says[2] that, "previous to the glacial epoch, the greater part of the Laurentian basin discharged its waters southward to the Mississippi and . . . during the first advance of the ice from the north the drainage was not obstructed so as to form important lakes". Westgate[3], in tracing out the de-

[1] Bigelow. Bul. geol. soc. Am. 9:183.
[2] Lakes of North America, p. 97.
[3] *Loc. cit.* p. 92.

velopment of the Mississippi drainage system, considers that the flow of the Laurentian drainage system was southward into the predecessor of the Ohio river. As has already been shown, Spencer's eastward flowing river system can be originated only by a complete readjustment of the drainage, resulting from a great relative depression of the eastern uplands. Such a system could only come into existence after the valleys had been formed for it, and hence, as far as the history of the lake basins is considered, no such river system is required, and, unless positive proof of its former existence is forthcoming, it may be dismissed as hypothetic. One of the most important theories of the origin of the Ontario and other lake basins, and one which has had, and still has many prominent advocates, is that of glacial erosion, either entire or preceded by river erosion. This explanation was first most strongly urged by Prof. Newberry, and it has found its most recent able supporter in Prof. Tarr. It is impossible to do full justice to this view in the present limited space. Ice erosion is a factor the potency of which has often been overlooked, but of the importance of which there can be no question. We may however question whether a valley which, like that of Ontario, lies transverse to the general direction of ice movement in this region, can owe much of its depth to this agent. The following considerations will be helpful in understanding the influence of glacial erosion on preexisting topography. If a valley like that of Lake Ontario is occupied by a glacier the motion of which is parallel to the trend of the valley, the topographic relief is likely to be accentuated by ice erosion. If the motion of the ice is transverse to the direction of the valley, the erosion tends to obliterate or at least reduce the relief features. If, however, a mass of ice remains stagnant in the valley, the upper strata of ice may override it, and the amount of glacial erosion is reduced to a minimum. The striae in this region, together with the direction of slopes from the oldland, point to a southward movement of the ice, and Gilbert has shown that the amount of erosion on the edge of the escarpment in western New York is comparatively slight.[1] Hence we may assume that the basin of Ontario was mainly *occupied* by ice during the

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[1]Bul. geol. soc. Am. 11:121.

glacial period, but that comparatively little erosion was accomplished. This is farther borne out by minor relief features, such as the benches shown in sections 4, 5 and 6, in the southern wall of the basin, and which probably consist of harder beds which erosion has left standing out in relief. On the theory of glacial erosion, we might expect these to be absent, or at least much less prominent, since ice would hardly show such selective power as is attributable to running water and atmospheric agents.

With the failures of the theories that an eastward flowing stream or glacial ice produced the Ontario valley, we are forced, with Upham, Russell and others, to look on a westward flowing stream as the most probable agent in the production of this valley. As has before been shown, such a stream would be the normal result of a gradual development of a drainage system on an ancient coastal plain of the type here considered.

Ancient St Davids gorge. Since the time of Lyell, the old buried channel from the whirlpool to St Davids has played a prominent part in the discussion of the life history of Niagara. For a long time it was considered to be the preglacial channel of Niagara, or its predecessor, the Tonawanda. More recently it has been considered of interglacial age, eroded by an interglacial Niagara, during a temporary recession of the ice sheet from this region, and filled with drift during a readvance of the glacier. The most satisfactory interpretation of this channel however makes it independent of the Niagara, and considers it one of many preglacial or interglacial channels which were formed by streams flowing over the edge of the escarpment and which increased in length by headward gnawing of their waters. This type of stream we have learned to call *obsequent*, its direction of flow being contrary to that of the master stream to which its waters eventually become tributary. An illustration of channel-cutting by streams flowing over the edge of a cliff, may be seen today in the chasm near the Devil's hole, on the American side of the gorge below the whirlpool. This gulch was cut by the little stream known as the Bloody run, which during the summer season dries away entirely.

The St Davids gorge has a width of nearly 2 miles at the edge of the escarpment. As will be seen by a glance at the map, it nar-

rows perceptibly southward, till at the whirlpool its width is less than the average width of the Niagara gorge. What the depth of the gorge is has not been determined, though from the depth of the whirlpool, we may assume that its floor is 200 feet or more below the level of Lake Ontario. At, and to the north of the escarpment it probably equals in depth Lake Ontario, opposite to it. The channel is undoubtedly much more irregular than is shown on the map, the sides being probably much diversified by lateral gullies. The great width of the channel at St Davids may perhaps be due in some small degree to widening by glacial erosion; for we know that the channel was occupied by ice, from the glacial scratches which are preserved on its walls, where these are exposed in the present ravine of Bowman's creek near the whirlpool. The influence of this buried channel on the direction and width of the Niagara gorge will be discussed later.

Valley of Georgian bay. Georgian bay is in many respects the analogue of Lake Ontario. Like the latter, it also occupies a valley lying between the Niagara escarpment and the crystalline old-land on the northeast. As has previously been shown, the Niagara escarpment extends northward from Hamilton into the Indian peninsula between Georgian bay and Lake Huron, and, after passing the Cove island channel, it reappears in the northwestern face of Grand Manitoulin island. At Cabot's head, on the Indian peninsula, the escarpment rises to 324 feet above the surface of the water, while just off the promontory soundings show a depth of 510 feet, thus making the total hight of the escarpment at this point 834 feet. In some places the summit of the escarpment rises to an elevation of 1700 feet above tide, or more than 1100 feet above Georgian bay (Spencer). The depth of the transverse channel connecting Georgian bay and Lake Huron has been found to be 306 feet, which is more than 200 feet less than the depth of the channel of Georgian bay. It is possible however that the soundings do not show the absolute depth of the rock bottom in the channel; for there may be a filling of drift which raised the bottom of the channel above that of the bay.

The valley of Georgian bay is continued northwestward in the channel known as North passage, a narrow body of water lying between the Manitoulin islands and the Canadian old-land. The southward continuation of the lowland is blocked by drift; but a number of borings, between the southern end of Georgian bay and Lake Ontario, east of Toronto, have developed the existence of a buried channel, which connects these two valleys. This channel is considered by Spencer to mark the pathway of his former Laurentian river. It is clear however that this valley is merely the buried connecting part of the inner lowland which extends along the base of the entire Niagara escarpment. This portion of the lowland was originally occupied by two streams flowing, the one northwesterly into the ancient Saginaw, the other southeasterly into the Dundas. The divide between the two may have been in the neighborhood of Lake Simcoe. It is however not at all improbable that the tributary of the Dundas may have, owing to favorable conditions, gained an advantage over that of the Saginaw, and pushed the divide northward. Such a migration of the divide might have resulted in the diversion of the upper waters of the Saginaw by capture, so that they eventually became tributary to the Dundas. This would account for the greater depth of the Georgian bay lowland, which, after the capture of the upper Saginaw waters, could be deepened independently of the notch in the cuesta through which its waters were formerly carried out. This of course is merely suppositional, and the truth can be established only by more detailed study of the ground. It is however what we might expect to happen in the normal adjustment of a coastal plain drainage. This hypothetic relation is illustrated in fig. 6.

The Huron lowland and the Chippewa and Tonawanda valleys. On the yielding strata of the Salina group a second lowland was carved out by subsequent streams, leaving an escarpment capped by the Devonic limestones on the south. This, as we have seen, becomes prominent eastward in the Helderberg range, where the third upper Devonic escarpment unites with it. In the Niagara region it faces the Tonawanda and Chippewa lowlands, which were probably opened out by a subsequent stream tributary to the an-

cient Dundas river. Throughout western Ontario this escarpment is buried by drift, but its presence is indicated by borings, which also prove the continuance of the lowland accompanying it. This escarpment, the inface of the second cuesta, becomes a very prominent feature in Lake Huron, where it is entirely submerged. It is however perfectly traceable from north of Goderich in Canada to the island of Mackinaw. Soundings prove it to have a hight of from 350 to 500 feet or more above the lowland which it faces. This lowland constitutes the deeper portions of Lake Huron, the shallower southwestern area being a part of the upland drowned by the backward setting of the water over the top of the escarpment. The following cross-section (fig. 9) from Point au Sable, north of Saginaw bay, to Cape Hurd, the northern extremity of the Indian peninsula, passes across the highest portion of this escarpment at the 9 fathom ledge and diagonally across the deepest portion of the Huron lowland, where the soundings reach a depth of 750 feet. This apparently marks the location of the preglacial Saginaw river, which probably breached the second cuesta to the south of the 9 fathom ledge, though no channel is indicated by the soundings.

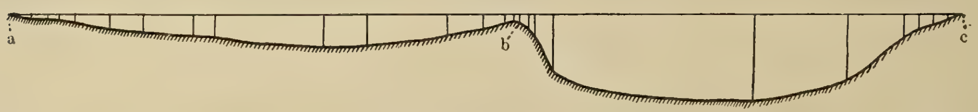

Fig. 9 Section across Lake Huron from Point au Sable, a) across 9 fathom ledge, b) to Cape Hurd, c) (For location of section *see* fig. 6).

We have now traced the development of the topographic features of the Niagara district, and have found this to be in conformity with the laws governing the normal development of drainage systems on an ancient coastal plain. The only abnormal features which need to be considered now are the tilting of the land and the filling of most of the old channels by drift, converting the lowlands into lake basins and reversing the drainage of the unfilled channels. These were the catastrophes which immediately preceded the birth of Niagara and which were directly responsible for its existence. To these and the life history of Niagara, attention will now be invited.

Plate 5

" Rock of Ages ", the largest of the fallen limestone fragments at the foot of Luna falls, on the American side (Copyright by Underwood & Underwood, New York)

Chapter 2

LIFE HISTORY OF NIAGARA FALLS

Glacial period

Two important events immediately preceded the birth of Niagara. The first was the formation of a series of great lowlands and cuestas by stream and atmospheric erosion during a period of time when, according to all indications, the land stood from 2000 to 5000 feet higher than it does now. This was outlined in the preceding chapter. The second event was the accumulation of a great mantle of glacial ice over most of northeastern North America, and the modifications of the previously formed erosion topography, either by the erosive action of the ice or by deposits left on its melting. The time equivalent of the latter event is commonly known as the glacial period of the earth's history, a remote period as time is ordinarily counted, but a very recent one in the chronometry of the geologist. Contemporaneous with this great accumulation of ice was probably the subsidence of the northern part of this region, thus changing the slope of the land surface from a southward to a northward one.

The greatest accumulation of ice during the glacial period appears to have been in the region to the north and northeast of the great lakes, or in general over the area of the Laurentian old-land. The immediate causes which brought about such accumulation, were the extensive refrigeration of the climate and the increased precipitation of moisture, so that a greater amount of snow fell during the winter seasons than could be removed by melting during the succeeding summers. The partial melting and refreezing of the snow, which continued over a long period of time, eventually resulted in producing glacier ice, after the manner of the formation of glaciers at the present time.

The thickness of the great Laurentian glacier, which eventually covered all the land of this region, including even the highest mountains, must be estimated at thousands of feet in its central part with a progressive diminution of thickness toward the margin. The ice

of glaciers, as is well known, has a certain amount of plasticity and will flow under the pressure of its own weight, somewhat after the manner of a mass of pitch. The flow of the great Laurentian glacier was outward in all directions from the center of accumulation, local topographic features exerting a deflecting influence only in the more attenuated marginal portions. In its basal portions, the ice was well supplied with rock debris, from the finest rock flour and clay to boulders often of very great size. This material was derived from the surface over which the ice flowed, and it measured in part the amount of erosive work which the ice had accomplished. The rock fragments frozen into the bottom of the moving ice mass, served as efficient tools for grooving and scratching the bedrock over which the ice flowed, while at the same time the finer material smoothed and polished the rock surfaces. The direction of the grooves and striae on the rock surfaces in general indicate the direction of the movement of the ice which produced them, but this may not always represent the direction of general ice movement for the region, since, at the time of making the striae, the ice may have been thin enough to be influenced by the local topographic features of the region. In the Niagara district the striae have a direction extending about 30° west of south (Gilbert) which direction, being inharmonious with the trend of the lowlands, indicates that these striae were formed by the general movement of the ice, rather than by local movements, controlled by topography.[1]

While the surface rocks of this region were everywhere scratched and polished by the ice, these markings are only exhibited where the protecting mantle of loose surface material or drift has been recently removed. For where the polished rock surfaces are exposed for any considerable period of time, weathering usually obliterates these superficial markings. The best place in which the striae of the region about Niagara river may be studied is near the quarries on the edge of the escarpment, a mile or more west of Brock's monument, where the ledges are progressively uncovered previous to quarrying.

[1] For an account of the glacial sculpture in this region, *see* Gilbert. Bul. geol. soc. Am. 1899. 10:121.

Throughout the greater part of the district, the polished rock surfaces are covered by a coating of drift of very varying character and thickness. This was the ground moraine or till of the Laurentian glacier, and represents the rock debris which was frozen into the bottom of the ice, and carried along in its motion, till liberated by the melting of the ice. This ground moraine, either in its original heterogeneous character or modified by the agency of running water, filled most of the old river gorges through which the drainage of preglacial times found its exit. Some of the shallower lowlands, like that of the Tonawanda, were also filled with drift, while the more profound ones, like the Erie and Ontario lowlands, received only a partial drift filling.

The partial obliteration of the old drainage channels, which was thus brought about, together with a depression of the land on the northeast to a depth below that at which it now stands, converted the unfilled lowlands into lake basins, apparently reversed the drainage of many streams, forcing them to cut gorges where their old channels were drift-filled, and finally became the immediate factors in the formation of Niagara.

Lacustrine period[1]

During the slow melting of the glaciers in the Laurentian region, and the resultant northward retreat of the front of the ice, large bodies of water, of varying depth and extent, were held in front of the ice sheet, which formed a dam across the northeastern part of the lowland country, the general slope of which was now toward the ice instead of away from it. The elevations of these glacial lakes were determined by the lowest uncovered passes in the margins of the lake basins across which the discharge took place, and, as during the continued melting of the ice dam, lower passes were progressively uncovered, the outlets were successively transferred to them and the levels of the lakes sank correspondingly.

[1] For a detailed account of the successive stages in the development of the great lakes, the shore lines, outlets and extent of each, the reader is referred to the papers by Gilbert, Spencer, Taylor, Leverett, Fairchild and others, cited in the appendix.

Though of a temporary nature, these bodies of water endured sufficiently long to permit the formation of well marked beaches with their accompaniment of bars, sand-spits and other wave-formed features. These have been carefully studied and mapped by a number of observers, and the general extent and outline of these lakes is today pretty accurately determined.

The largest of these glacial lakes, though not the first to come into existence, was glacial Lake Warren. "At its maximum extent Lake Warren covered the south half of Lake Huron, including Saginaw bay, the whole of Lake Erie and the low ground between it and Lake Huron; extended eastward to within twenty or thirty miles of Syracuse, N. Y. and probably covered some of the western end of Lake Ontario."[1] The retaining ice wall on the east extended in a northwesterly direction, across western New York, Lake Ontario and the northeastern end of Lake Huron. This position of the ice front is in part inferred from the existence of moraines of sand and gravel along a portion of that line. The total area of this ancient lake has been variously estimated as including from one hundred thousand to two hundred thousand square miles of surface but this estimate is based on the assumption that the lake occupied the greater part of the area of the present upper Great lakes, with the intervening land, a supposition which Taylor holds to be incorrect. The area of Lake Warren was probably less than 50,000 square miles, or approximately half that of the state of Kansas. The extent and level of this lake was not constant, there being many oscillations, due chiefly to warpings of the land surface. These oscillations are recorded in the various beaches which have remained to the present time. The chief outlet of Lake Warren was by way of the Grand river valley into the valley of Lake Michigan, the southern end of which was then much expanded and occupied by the waters of "Lake Chicago." The outflow of this lake was to the Mississippi by way of the Illinois river, across the divide near where Chicago now stands, thus temporarily reestablishing the southward drainage of this region.

[1] Taylor. A short history of the Great lakes, p. 101.

As the ice front continued to melt away, retreating northeastward, drainage at a lower level was permitted along the ice front to the Hudson valley, and the sea. As a result, the water level sank, the Chicago outlet was abandoned, and Lake Warren became much contracted and in part cut up and merged into new bodies of water. The largest of these was glacial Lake Algonquin, which occupied the basins of the three upper Great lakes, and seems to have been for a long time independent of Lake Erie, which after the division of Lake Warren was for a time much smaller than it now is. (Fig. 11 and 13)

The critical period in the development of the lakes, with reference to the birth of Niagara, was the uncovering of the divide at Rome (N. Y.) and the consequent diversion of the drainage into the present Mohawk valley. This brought with it a subsidence of the waters north of the Niagara escarpment to the level of this outlet, which was considerably below that to which the other lakes could subside, owing to the rocky barriers which kept them at greater altitudes. As a result Niagara river came into existence, though at first it was only a connecting strait between Lake Erie and the subsiding predecessor of Lake Ontario. The overflow from Lake Erie occurred at the present site of Blackrock, because there happened to be the lowest point in the margin of the lake. It is not improbable that a small preglacial stream had predetermined this point, either flowing southward into the river occupying the Erie basin, or northward as an obsequent stream into the Tonawanda. The course of the river below Blackrock was determined by the directions of steepest descent of the land surface, which was probably predetermined to some extent by preglacial streams. As soon, however, as the level of the waters of the Ontario valley sank below the edge of the Niagara escarpment at Lewiston, a fall came into existence, which daily increased in hight as the level of the northern lake was lowered. From that time to the present, Niagara has worked at its task of gorge-cutting, the present length of the gorge, from Lewiston to the falls, marking the amount of work accomplished.

When the waters north of the escarpment had subsided to the level of the outlet at Rome, a long period of stability ensued, during which extensive and well marked beaches were formed by the waves. This comparatively long-lived body of water has been named Lake Iroquois, and its outline is shown in the accompanying map (fig. 10) reproduced from Gilbert's *History of the Niagara river*. The Iroquois shore lines in this region may be seen in the ridge road which extends eastward from Lewiston, and westward from Queenston, closely skirting the foot of the escarpment.

Fig. 10 Map of Lake Iroquois; the modern hydrography shown in dotted lines. (After Gilbert)

A fine section of this old beach is seen just behind the railroad station at Lewiston. Here the layers of sand and gravel slope steeply toward the southeast, and many of them are irregular and wedge-shaped. Some of the beds, a foot or more in thickness, consist entirely of rounded pebbles, with little or no sand between, forming a porous mass of "loose gravel". The prevailing rock of the pebbles is the Medina sandstone, derived from the neighborhood, and the pebbles are always well waterworn, and commonly of the flattened type characteristic of thin bedded rocks. Mingled with the beds of coarse material are layers of fine sand, the structure of which is well brought out by exposure to wind and weather. Not

infrequently masses of sand and pebbles are cemented into a conglomerate by calcite or other cementing agents.

The terminal portion of the beach at the Lewiston station is rather exceptional. It has here the character of a sand spit, extending toward the Niagara river. Between this spit and the escarpment there is a low area of irregular outline, something over half a mile in width along the river and extending perhaps three fourths of a mile eastward from it. This area is bounded by steep erosion cliffs of unconsolidated material, and is from 30 to 50 or more feet lower than the level of the ridge road. The suggestion presents itself, that these features may be due to the current of the Niagara at its *embouchure* into Lake Iroquois, at a time when the falls were probably not far distant. (*See* plate 3 and map)

There is evidence that the level of Lake Ontario at one time stood much lower than it does at present; for the bottom of the lower Niagara, from Lewiston to the lake, is from 100 to 200 feet below

Fig. 11 Gilbert's map of the Great lakes at the time of the Trent river outlet. Modern hydrography dotted.

the present water level. In fact, the old beaches about Lake Ontario indicate a number of oscillations of level, similar to those recorded in the other glacial lakes, and due chiefly to crust warpings.

Lakes Algonquin and Iroquois were probably contemporaneous, and it is believed that for a time the former discharged its waters to the latter by way of Balsam lake and along the course of the Trent river. This discharge by way of the Algonquin river, as this old outlet of Lake Algonquin has been called, robbed the Niagara river of seven eighths of its water supply, which up to then had reached it by the present course through the Detroit river. As a result, the volume and erosive power of the river were for a time enormously diminished. (Fig. 11 and 13)

Fig. 12 Gilbert's map of the Great lakes at the time of the Nipissing outlet. Modern hydrography dotted.

During the farther retreat of the ice front, a still lower pass was opened by way of Lake Nipissing and the Mattawa river into the Ottawa. By the time this outlet was opened, the ice had also disappeared from the St Lawrence valley, and the outlet of the waters of the great lakes was transferred from the Rome channel to the one at the Thousand islands, Lake Iroquois at the same time subsiding to Lake Ontario. (Fig. 12 and 14)

The successor of Lake Algonquin, after the change from the Balsam lake to the Nipissing lake outlet, has been named by Taylor, Nipissing great lakes, while the river which carried its discharge to the Ottawa was called by him the Nipissing-Mattawa (fig. 14).

With the gradual melting away of the great ice sheet, the land on the northeast began to recover from its last great depression,

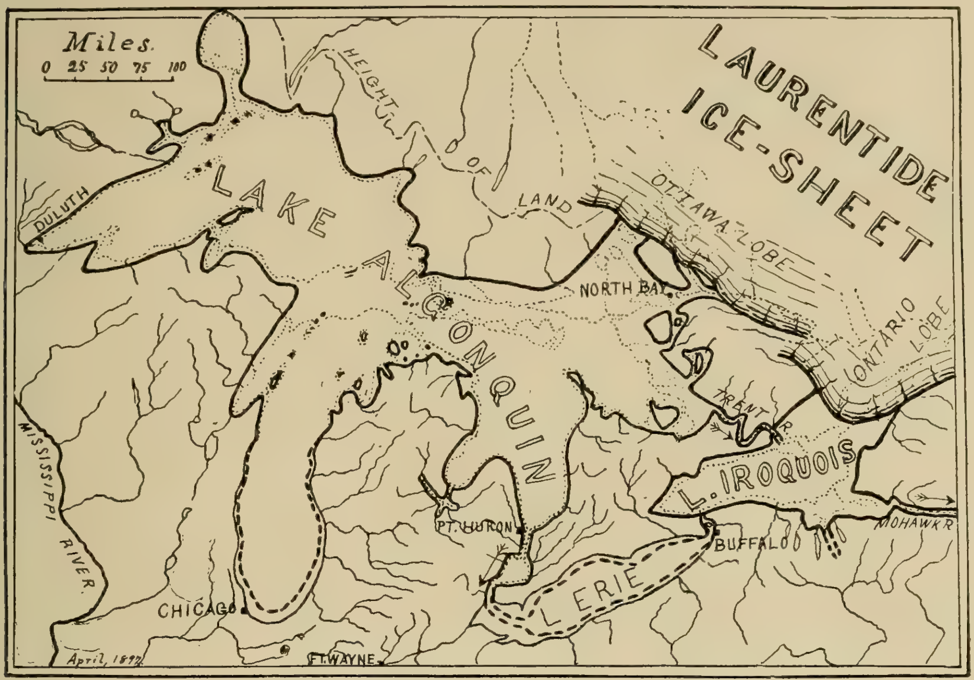

Fig. 13 Taylor's map of Lakes Algonquin and Iroquois.

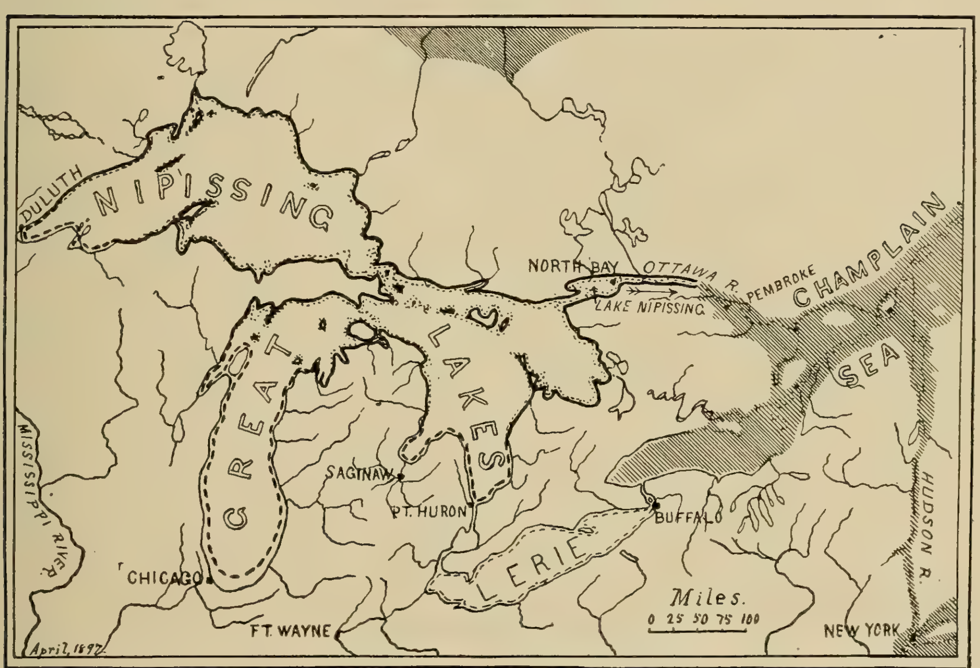

Fig. 14 Taylor's map of Nipissing great lakes and the Champlain submergence.

and, though there had been many oscillations, the balance of change was toward a slow but steady elevation of the Laurentian region. As a consequence the beaches of the old glacial lakes, which of

course had a uniform elevation while forming, are no longer of uniform hight above sealevel, but rise progressively toward the northeast. This slow rising of the land caused a gradual canting of the basins, which brought with it a relative fall of the waters along the northeastern shores and a corresponding relative rise of the waters along the southwestern shores. Such a progressive change eventually carried the Nipissing and Balsam lake outlets above the level of the outlet at Port Huron, and the present drainage was reestablished. As the canting affected the Erie basin as well as the others, it caused a progressive elongation of that lake toward the southwest, thus finally giving it its present size and shape. This same canting also resulted in the farther separation of the upper lakes into their present divisions.

While this general outline of the lake history is held by many geologists, others, notably Upham, combat it strongly. Mr Upham holds that the elevation of the land in the northeast had progressed to such an extent by the time the ice had uncovered the northern outlets of Lakes Algonquin and Nipissing, that these passes had been raised above the altitude of the outlet at Port Huron, and that hence these passes never, or but for a brief period of time, served as outlets for the waters of the upper lakes. If this is the case, Niagara always carried the drainage of the upper great lakes as well as Lake Erie, and its volume was approximately uniform throughout its history. The strong erosion features, however, which are found in the Mattawa valley indicate that a large stream discharged here for a considerable period of time; and, if such was the case, it is highly probable that the present Port Huron outlet was not then utilized, and that consequently the Niagara was robbed of the discharge of the upper lake area. The influence on the erosion of the gorge by such a withdrawal of the water must have been a pronounced one, and we shall see later that certain portions of the gorge may well be explained by this hypothesis. During the time of the overflow of the upper waters by way of the Nipissing-Mattawa river it is not improbable that, as held by Taylor and others, the sea had access to the St Lawrence and Ontario basins and possibly to the basins of the upper lakes. This would account for the occurrence of marine types of organisms in the deeper portions of some of the present

great lakes as well as for the maritime species of plants found in the lake district. It must however be borne in mind that this marine invasion was not till after the time of Lake Iroquois, for fresh-water fossils have been found in the beaches of this lake.

The tilting of the land, which is recorded in the deformed beaches, has not yet ceased, as recent investigations in the lake regions clearly prove. Mr Gilbert has made an extended study of this problem; and he has been led to the assumption "that the whole lake region is being lifted on one side or depressed on the other, so that its plane is bodily canted toward the southsouthwest, and that the rate of change is such that the two ends of a line 100 miles long and lying in a southsouthwest direction are relatively displaced .4 of a foot in 100 years". From this it follows that "the waters of each lake are gradually rising on the southern and western shores or falling on the northern or eastern shores, or both". This implies of course a drowning of the lower courses of all streams entering these lakes from the southwest and an extension of those entering from the northeast. Assuming that the rate and character of change will be constant in the future, the following interesting results have been predicted by Mr Gilbert. The waters of Lake Michigan at Chicago are rising at the rate of 9 or 10 inches a century; and "eventually, unless a dam is erected to prevent, Lake Michigan will again overflow to the Illinois river, its discharge occupying the channel carved by the outlet of a Pleistocene glacial lake. . . Evidently the first water to overflow will be that of some high stage of the lake and the discharge may at first be intermittent. Such high water discharge will occur in five hundred or six hundred years. For a mean lake stage such a discharge will begin in about one thousand years, and after one thousand five hundred years there will be no interruption. In about two thousand years the Illinois river and the Niagara will carry equal portions of the surplus water of the great lakes. In two thousand five hundred years the discharge of the Niagara will be intermittent, falling at low stages of the lake, and in three thousand five hundred years there will be no Niagara. The basin of Lake Erie will then be tributary to Lake Huron, the current being reversed in the Detroit and St Clair channels."[1]

[1] Gilbert, G. K. Recent earth movements in the great lake region. 18th an. rep't U. S. geol. sur. 1896–97. pt 2.

Fluvial period

Niagara falls came into existence when the waters of Lake Iroquois, the predecessor of Lake Ontario, fell beneath the level of the escarpment at Lewiston. At first it was only a small cataract, but day by day, as the lake subsided, it gained in hight and consequently in force of fall, as well as efficiency in cutting its channel. That the entire gorge from Lewiston to the present falls is the product of river erosion is scarcely questioned by any one today, but there are excellent reasons which lead some to believe that this cutting was not wholly the work of the Niagara. When the falls were at Lewiston, the Niagara was a placid stream from Lake Erie to near the falls, much as it is today from Buffalo to the northern end of Grand island. Its banks consisted chiefly of glacial till, into which terraces were cut by the stream, most of which are visible at the present day. The lower ones are well marked in Prospect park, though there they have been grassed over and modified to a considerable extent. From Niagara falls to the railroad bridges at Suspension Bridge, on the New York side of the river, the old bank runs parallel to the edge of the gorge and at a short distance inland from this. From Suspension Bridge to the whirlpool it makes a curve somewhat more crescentic than that of the margin of the gorge, and a similar curve from the whirlpool to Bloody run at the Devil's hole. On the Canadian side these old river banks can be traced from above the falls almost to Brock's monument, and in some cases two or three successive terraces are recognizable. In Queen Victoria park they constitute the steep slope which bounds the park on the west, and parts of which are still actively eroded. Less than a mile below the carriage bridge, the old banks approach close to the modern one and continue, almost coincident with it, to the railway bridges at Clifton. From here to the whirlpool the old river margin has a nearly straight course, while the modern one is curved, and a similar relation holds below the whirlpool, though here, from the great curvature of the modern channel, the old banks are in places nearly a mile distant.[1] (Plate 6)

[1] These old river banks are indicated on the geologic map by dotted lines; the localities where shells have been found are shown by crosses.

Plate 6

Old banks of the Niagara on the New York side, below the railroad bridges (U. S. geological survey)

Within the old channel thus outlined, which was much broader than the modern channel below the falls, accumulations of stratified sands and gravels were formed in the more protected places, much as such deposits are formed in streams today, where sands are swept into protected areas. With these sands and gravels were swept together the shells of those mollusks which lived in the river water, and many of which were of the species now found living in the upper Niagara.[1] Most of the shells thus swept together were probably of dead individuals, though living ones may also have been carried into these growing deposits. Many excavations have been made in these ancient deposits, fragments of which are preserved in various places between the former and present banks of the river. The most notable of these and the one longest known is on Goat island, perhaps a quarter of a mile inland from the edge of the cliff, at the Biddle stairway. In the section opened here, most of the material is seen to be coarse and rudely stratified. The pebbles are subangular, often quite angular, while some appear to be scarcely worn at all. Blocks a foot or more in diameter are not infrequent, the material being generally limestone from adjoining ledges, though fragments of sandstone and of crystalline rocks are not uncommon. Occasionally a lens of fine sand occurs which shows cross-bedding structure, the laminae pointing in a northwesterly direction. The shells are found on the cross-bedding planes, conforming with them, and indicating that they were spread there by the current which moved the sand grains. Among the coarse material the shells are mixed indiscriminately. In many cases the gravels are of the loose type, with scarcely any sand between them, indicating deposition by a powerful current. Along these zones air and water have most readily penetrated, and a deposition of iron oxid has been formed which stains both pebbles and shells. The shells are generally very fragile, and commonly show signs of wear. Gastropods are most abundant in the Goat island gravels.

In Prospect park several excavations formerly exposed these gravels. The deposit here consists of sand and gravel with the pebbles moderately rounded, though occasionally subangular, and

[1]For descriptions and illustrations of these shells, *see* chapter 5.

varying in diameter up to 6 inches or a foot. The stratification is rude, and shells are abundant. These are mostly fresh-water mussels (Unio, Alasmodonta, etc.) and the valves are generally found in conjunction, a fact which may indicate that these shells lived here. Small gastropod and pelecypod shells are plentifully mingled with the pebbles and sands. Below this are coarser deposits where boulders up to several feet in diameter occur, and below this occurs a bluish clay. In all of these beds shells have been sparingly found.

Several excavations have been made in Queen Victoria park, and here shells are common. The Unionidae appear to be most abundant, though small gastropods are not uncommon. All appear to have been more or less waterworn. The mussel shells are generally decayed, owing no doubt to percolating waters. Below Clifton, the lower of two terraces is of a somewhat sandy character, though many boulders occur in it. Shells of unios occur sparingly in these deposits, and a few small gastropods were found in the lowest terrace. Farther north several excavations in the lower terraces of the old river show loose gravels alternating with a sort of till, a few Goniobasis and other gastropod shells being found here. In some cases the gravels have become cemented into a conglomerate by a deposit of calcite between them, often of considerable thickness. Boulders of similarly cemented gravels are found in the gorge below, at the whirlpool.

It will thus be seen that, throughout the greater part of the young Niagara, deposition was going on as well as erosion. The amount of erosion of the river bed was probably very slight, that of the banks being much more pronounced. The chief part in the cutting of the gorge was enacted by the cataract, which cut *backward* from Lewiston, the amount of *downward* cutting by the river being insignificant. The manner in which the cataract performed its work of cutting may today be observed in both the American and Canadian falls, as well as in waterfalls of other streams falling over strata, the arrangement of which is similar to that obtaining at Niagara. The essentials are a resistant stratum overlying a weak one, the latter being constantly

Plate 7

Cliff on the Canadian side of the gorge, showing the receding base. The giant icicle marks the edge of the overhanging ledge (Copyright by Underwood & Underwood, New York)

worn away by the spray generated by the falling water, thus undermining the resistant layer. Such undermining may be seen in the Cave of the Winds. In course of time this undermining progresses so far that the projecting portion of the capping stratum breaks down for want of support, and the crest line of the fall becomes abruptly altered. The fallen fragments accumulate at the foot of the fall, where they will remain if the force of the water is unable to move them, as illustrated by the rock masses lying at the foot of the American fall. If, however, the force of the falling water is great as at the Horseshoe falls, these blocks will be moved about, perhaps even spun about, and so made to dig a deep channel below the falls. In the soft rocks which lie at the foot of the Horseshoe falls a channel probably not less than 200 feet in depth has been dug in this manner. (Fig. 15)

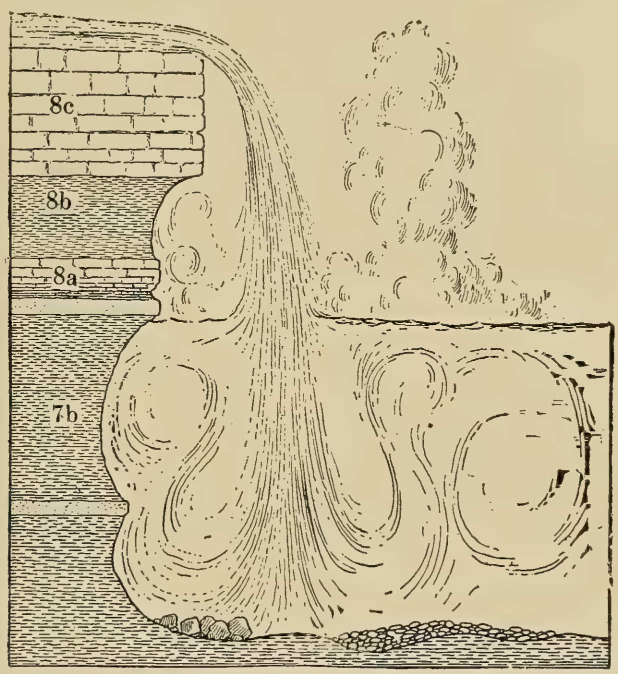

Fig. 15 Sectional view of the Horseshoe falls showing arrangement of strata, and depth of water below falls. (After Gilbert) The numbering of beds corresponds with that of table.

When we consider the Niagara gorge in detail we find it to be much more complex than would at first appear. The first abnormal feature which presents itself in a map view of the entire gorge is the bi-crescentic character of its course, with the rectangular turn at the whirlpool, a course very different from that which we are accustomed to find in large rivers whose direction of flow

has been uninfluenced by preexisting relief features. (Fig. 16) Another feature of importance is the varying width of different parts of the gorge, and the corresponding increase in velocity of current in the narrower parts. The depth of the channel also varies in different portions of the gorge, being in general greater in the wider and less in the narrower parts. (Fig. 18)

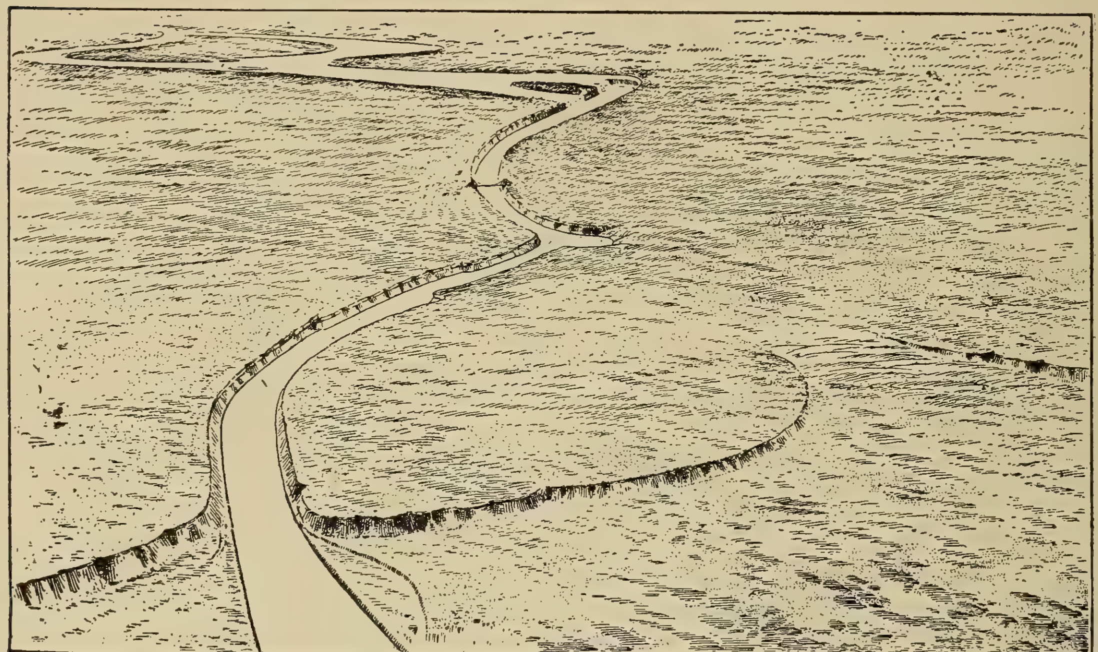

Fig. 16 Birdseye view of Niagara gorge showing the course of the river; the falls, the railroad bridges, whirlpool, location of Fosters flats, escarpment at Queenston and flaring mouth of old St Davids gorge. (After Gilbert)

The first mile and three fourths of the gorge, or that portion marking the retreat from the escarpment to the Devil's hole, extends nearly due south, and is fairly uniform in width, comparatively narrow, and with a current of great velocity. The narrowness of this stretch, when compared with the channel made by the present cataract from the railroad bridges southward, seems to indicate a smaller volume of water during its formation than that now passing over the falls. An alternative hypothesis accounts for the narrowness of this section of the gorge by assuming it to be a preglacial drift-filled channel, made by an obsequent stream flowing northward to the Ontario lowland, similar to that which made the old St Davids channel, but reexcavated by the Niagara. It is highly probable that there was at least a shallow channel which served as

a guide to the young Niagara. The southward continuation of this channel beyond the Devil's hole, is found in the valley of Bloody run, a shallow but distinct depression now followed in part by the Lewiston branch of the New York Central railroad and evidently of preglacial origin, as its floor is covered with till.

Next above this lowest section of the gorge is one, in general much broader, and extending in a southwest direction from the Devil's hole to the whirlpool, a distance of a little less than two miles. This section is contracted near its middle by the projection from the Canadian bank, known as Fosters flats, or Niagara glen. The river is here scarcely 300 feet wide, though the tops of the banks are in places over 1700 feet apart. Above Fosters flats and almost as far as the whirlpool, the river is very calm, and apparently deep, while at the point of contraction at the southern end of Fosters flats, the waters suddenly become tumultuous and rush through the narrow channel with great velocity. This sudden change has been attributed to a sudden decrease in depth of the river at this point, but it is evident that, even if the channel had the same depth as above, the sudden contraction would produce a similar effect, for the waters, spread out over a broad and deep channel, on being suddenly forced to pass through a narrow one, would from mere crowding into a smaller space assume a violent aspect.

Niagara glen, or Foster's flats

PLATE 8

This is one of the most interesting places along the whole Niagara river, though generally little visited by tourists. From the Canadian side a platform of limestone projects, whose surface is a little below that of the general level of the upland plain, from which it is separated by a steep bluff. The platform is known as Wintergreen flat, and, though sparingly wooded, is very deficient in soil. The bluff which bounds it on the west is a part of the old river bank. On the remaining sides this platform is limited by abruptly descending cliffs, at the base of which are extensive talus slopes descending to a lowland of considerable extent. This lowland, which is known as Fosters flats, has its surface well strewn

with huge boulders of limestone. The cliff which limits Wintergreen flat on the northern or downstream side is the highest and most precipitous, and from its base a well marked, dry channel leads northward for a third of a mile to the river's edge. This channel is separated from the present river channel on the right by a ridge which appears to consist of huge limestone blocks, though its base is probably formed by undisturbed remnants of the lower strata of the region. The floor of this old channel is strewn with huge limestone boulders, such as are found at the foot of the American falls today, and its left bank is the precipitous west wall of the Niagara gorge. (Fig. 17)

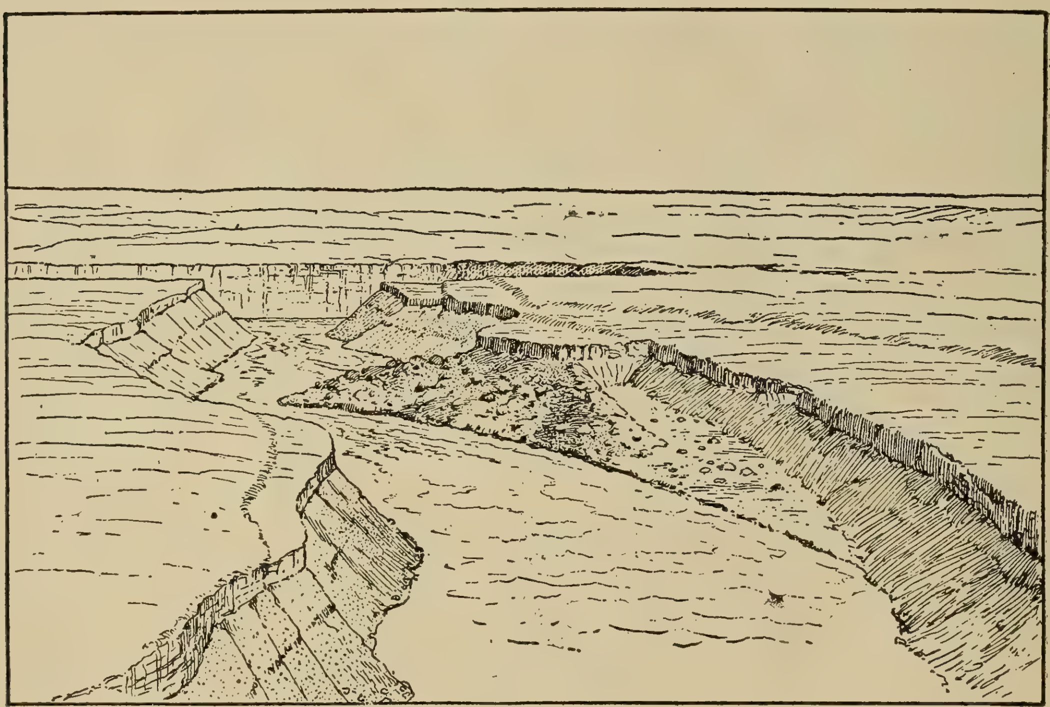

Fig. 17 View of Niagara glen or Foster's flats, looking south. Forests omitted. (After Gilbert)

These various features have been well explained by Mr Gilbert,[1] who holds that a narrow island comparable to Goat island, divided the fall in two, when it had receded to the northern end of Fosters flats. The foundations of this island, which has since crumbled away, are seen in the ridge which divides the old dry channel on the left from the main bed of the river. The eastern or American fall at that time was the larger of the two, and it receded more

[1]Nat. geog. monographs. Niagara falls and their history.

Plate 8

Wintergreen Flat looking south; showing the platform which was formerly the river-bed, and the cliff in the center which was once the site of a fall

rapidly. "When the Canadian fall reached the head of the island, the American had just passed it, and part of the sheet of water on Wintergreen flat was drained eastward into the gorge opened by the American fall. The Canadian fall, through the loss of this water, became less active, and soon fell out of the race."[1] By the final retreat of the American fall beyond the southern end of Wintergreen flat, the latter was left as a dry platform with precipitous sides, over which once poured a portion of Niagara's torrent.

While the occurrence of an island in the position pointed out by Gilbert was undoubtedly the immediate cause of the division of the falls, the more fundamental cause, and the one to which the island itself owed its existence, is to be sought elsewhere. From an inspection of the map the suggestion presents itself that there may be a vital connection between the abandoned falls at Fosters flats and the great bend of the river at the whirlpool. When a great river runs for a mile or more in a straight line, as the Niagara does above the whirlpool, and then abruptly turns to the right, the current is deflected by this sudden change in direction to the right bank of the river below the bend, which it continues to hug till again deflected. It is thus that the greatest amount of water will be carried along the right bank of the river, causing a deeper channeling there. When Niagara falls had receded to the present northern end of Foster's flats, the greatest amount of water was carried over its right side. The resulting deepening of the channel on the right, and the consequent drawing off of the water toward that side, was the cause of the appearance of the island (if such existed, as seems probable from the remaining foundation) above the water and the consequent division of the falls. A precisely analogous feature occurs in the lower falls of the Genesee river below Portage. Here, however, no island was formed, though in other respects the two cases are nearly alike. In the Genesee the change has occurred in comparatively recent times, and records of earlier conditions have been preserved. An abrupt bend of the river to the right, deflected the current to the right bank below the bend, and thus caused the deepening of the river bed on that side, as well as the more rapid

[1] Gilbert. Nat. geog. monographs. Niagara falls and their history.

recession of the right hand portion of the falls. In the course of a comparatively short time the channel became so deep on the right, and the falls receded so fast on that side, that all the water was drawn off from the larger portion of the river bed on the left, which today remains as a triangular platform comparable to Wintergreen flat, with steep sides, and several hundred feet wide, at its downstream end. The river now flows in a channel, in places less than 10 feet wide, and 100 feet below the level of the platform which was its bed less than 100 years ago. The present lower fall, having mostly receded beyond the upstream end of the platform, again extends across the entire bed of the river. The water in the river has not, as far as known, changed in average volume, though above and below the narrow part the gorge is many times as wide. All the water which passes in a thin sheet over a broad fall above the narrow gorge is forced to pass through this contracted portion, and presents a rushing current, though the bed is deeper here than where the gorge is broader. The time required for the recession of the fall over the space of the 2000 feet of narrow gorge, must have been much shorter than that required for the recession through a similar length in the broader portion of the gorge, for the concentration of the waters here enabled it to do much more effective work.

Judging by analogy, we may assume that the narrow channel opposite Foster's flats was cut by a stream of the full power of the present Niagara, but whose main mass of waters was carried over the right side of the fall on account of the bend in the stream above. The present Horseshoe falls is cutting a much narrower gorge than that to the north of it, owing to its peculiar position at the angle of a second great bend. (Fig. 19) From the fact that the cutting was most profound on the eastern or right bank of the river at Foster's flats, this bank has received the precipitous character which it has retained to the present day.

An interesting fact bearing on the interpretation of the history of Foster's flats, is the occurrence in the sands among the huge boulders near the foot of the ancient falls, of shells of the small fresh-water gastropod, Pomatiopsis lapidaria Say,[1]

[1] *See* chapter 5.

which is found living in the Niagara river today, but only on the rocks and boulders lying in the constant spray of the modern cataract.

After passing Foster's flats, the scene of greatest erosive activity seems to have been transferred to the left bank of the river. This is indicated by the verticality of this side of the gorge south of Foster's flats, which suggests active erosion, while the lowland known as Ongiara park opposite to this on the New York side of the river, with its enormous boulders scattered about, recalls the dry channel on Fosters flats or the foot of the present American fall, and suggests an amount of water insufficient to remove them. This may be accounted for by assuming that the nearness of the fall had

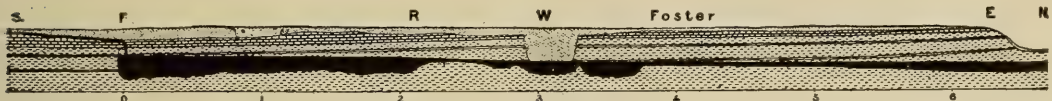

Fig. 18 Longitudinal section of the Niagara gorge from the falls F to Queenston hights E, showing strata of west bank and depth of channel. (After Gilbert) R railway bridges. W whirlpool. Foster = Foster's flats. Figures indicate miles.

given the river itself greater momentum above the fall, and that hence it dug deeper into the old drift-filled valley of the St Davids at the whirlpool. As a result, the deflection of the current to the right bank became more abrupt, striking the New York bank immediately south of where Ongiara park now is, and, being again deflected toward the Canadian side, it reached this just at the southern end of Foster's flats, thenceforth for a time causing the most active erosion on that side. The washing out of the drift from the old St David's channel furnished the river with tools with which it was able to cut down into its bed, so that in this portion erosion was probably both by backward cutting of the falls and downward cutting of the river above the falls.

We have so far considered the falls as of simple type, but it is by no means certain that such was the case. If we judged from analogy with other streams which have cut gorges in the same strata as those found at Niagara, we should suppose that, as in the case of these streams, a separate fall was caused at Niagara by each resistant layer. Thus in the lower Genesee river, at Rochester, one fall is caused by the upper hard bed of the Medina formation, an-

other by the limestone of the Clinton group, and a third by the Lockport limestone. In the Niagara river we might suppose that at least three, and possibly four, falls had existed at one time. The lowest of these would have been over a hard bed of sandstone, about 25 feet thick, and about 100 feet below the top of the Medina group. Another might have been caused by the hard capping stratum of Medina sandstone, 10 feet thick. A third over the 30 feet of Clinton limestone; while a fourth would have been formed over the Lockport limestone. The second and third would perhaps unite in one, as the shale bed between the two resistant layers is only 6 feet thick. It may however be objected that in a great cataract the force of the falling water is such as to cause uniform recession of all the layers, and that hence only one great fall existed.

The whirlpool

PLATE 9

Perhaps the most remarkable part of the entire gorge is its great swollen elbow, the whirlpool. Here the current rushing in from the southeast with great velocity, circles around the basin and finally escapes, by passing under the incoming current, through the comparatively narrow outlet, in a northeasterly direction. The waters in the whirlpool have probably a depth of 150 or 200 feet, but both the outlet and the inlet are shallow, for here ledges of the hard quartzose bed of the Medina formation project into the river, extending in the latter case probably across the channel. An examination of the walls of the whirlpool basin shows that rock is absent on its northwestern side, the wall here being formed of unconsolidated material or drift. This is best seen on descending to the edge of the whirlpool on the Canadian side, through the ravine of Bowmans creek. It will be observed that the Niagara has here exposed a cross-section of the ancient drift-filled channel which extends southeastward from St Davids. This channel appears to have been that of a preglacial stream of the obsequent type,[1] which was tributary to the streams of the Ontario lowland. Some geologists however, notably Mr Taylor, believe that this old channel may have

[1] *See* chapter 1.

Plate 9

The whirlpool from the Canadian side. The ledges projecting at the water's edge, at the outlet, are the gray band in the Medina

been formed by a river and cataract similar to the Niagara of today, during interglacial time. That this old channel was once occupied by ice is shown by the glacial scratches on the limestone ledges exposed in the western wall of the old gorge, where this has been cleared of drift by Bowmans creek, and it is apparent that the filling in by drift must have occurred after the ice occupation. An inspection of the map will show that a part of the present Niagara gorge, that containing the whirlpool rapids, is in direct continuation of the old St Davids channel, and that, a little above the railroad bridges, the Niagara makes a pronounced bend, which brings it in conformity with the direction of this channel. This suggests that there was at least a shallow depression, the insignificant southeastward continuation of the St Davids channel, which guided the waters of the Niagara in this direction. Here a question of great importance in the history of the Niagara presents itself. Did the ancient St Davids gorge end where is now the south side of the whirlpool, with only a shallow surface channel extending beyond this point, or was the gorge of the whirlpool rapids a part of the old St Davids channel, which was merely cleared by the Niagara of the drift that filled it? The latter condition was assumed to be the true one by Dr Julius Pohlman of Buffalo, a pioneer in the study of the Niagara gorge and the first to recognize the complexity of the channel and attempt to account for its varying character. The theory is still held by many geologists. On the other hand, Taylor and others think it more likely that the ancient gorge stopped where is now the inlet to the whirlpool, and that the gorge above it is the product of post-glacial erosion. If this view be accepted, the narrowness and shallowness of the gorge of the whirlpool rapids must be accounted for by some change in the volume of water during its formation. Taylor, who has studied this problem, has come to the conclusion that, during the time that the gorge of the whirlpool rapids was being excavated, the upper great lakes (then united into Lake Nipissing) discharged by way of the Nipissing-Mattawa river as already outlined, and that therefore Niagara drained only the shallow Lake Erie, the amount of water in the river being only one eighth its present volume. It is easy to see that such a reduc-

tion in volume would lead to a great decrease in cutting power, and that the resultant gorge would hence be much narrower and shallower than the one cut when the water supply was as large as at present. The Nipissing-Mattawa outlet was finally closed, as we have seen, by the elevation of the land on the north, and the upper lakes assumed their modern outlet by way of Port Huron. As a result the water supply of Niagara was greatly increased, and the broad and deep gorge, which extends from south of the railway bridges to the present falls, was cut by a cataract of the size of the present Horseshoe falls, which in addition carried the water now passing over the American falls. This correlation between change in drainage of the upper lakes and change in size of the gorge of Niagara is certainly very suggestive, and seems admirably to account for many features observed in the gorge. For example, it explains satisfactorily the sudden widening of the gorge just before reaching the whirlpool, forming what Taylor has called the Eddy basin, from the strong eddy which characterizes this portion of the river. This wider part of the gorge Taylor believes was formed by the same large-volume river which cut out the broad channel north of the whirlpool, and he farther thinks, that the sudden change from this broad channel to the narrow one of the whirlpool rapids marks the reduction in volume of water on the opening of the Nipissing-Mattawa channel, which had hitherto been blocked by the remnant of the Laurentian glacier. There are however several features which must be satisfactorily explained before this theory (which Upham rejects on grounds already stated) can be accepted. It is highly probable that the gorge of St Davids was worn back beyond the whirlpool. From the great depth of the whirlpool basin, and the presence of the quartzose sandstone bed at the inlet to it, it seems probable that a fall existed here in the ancient stream which carved the St Davids channel. That channel has probably a depth similar to or greater than that of the part now constituting the whirlpool basin. Now, if, as we have reason to believe, this old channel was formed by an obsequent stream of moderate volume flowing northward to the Ontario lowland, it can hardly be assumed that there was but one continuous fall of from four hundred to five

Plate 10

The Whirlpool rapids and American bank, looking north. The talus above the gorge road covers the upper Medina sandstones and shales. The lowest projecting ledge consists of the two Clinton limestones; the talus above that covers the Rochester shales, and the upper cliff is of Lockport limestone. The upper gray Medina projects in one place, and shows the Clinton shale above it.

hundred feet in hight, with such a pronounced alternation of hard and soft layers. We must rather assume that a separate fall existed over each hard layer, and that, as in the other streams flowing northward over these same strata, these falls were separated from one another by considerable distances. If then, as is clearly indicated by the quartzose sandstone ledge at the inlet to the whirlpool, the lowest of these falls was at that place, the other two or three must have been at some distances up stream, and in that case it is not too much to assume with Pohlman, that the upper old falls over the Lockport limestone were somewhere near where the gorge is now spanned by the railway bridges. Taylor, however, does not encounter this difficulty, for he assumes that the St Davids gorge was formed by an interglacial Niagara, the great cataract of which, just before its cessation (probably through a southward diversion of the drainage) plunged as a single fall over the cliff into the basin now holding the whirlpool. To this view it may be objected that the old St Davids gorge is not such as would be formed by a single great cataract, since it flares out northward, having a width at St Davids of perhaps two miles. Such a form is more readily accounted for if one assumes that the valley was made by the headward gnawing of an obsequent stream and its various branches. Taylor meets this objection by invoking the action of readvancing ice to broaden the gorge, but, unless the last ice advance was from a very different direction from that indicated by the striae of this region, this hypothesis will scarcely hold. That direction, as already noted, is 30° west of south, while the direction of the old gorge is almost due northwest. Why may we not assume that only a portion, the southern one of the gorge of the whirlpool rapids, was carved by the Niagara during the time that its volume was diminished, and that the greater portion of this gorge was preglacial? This would greatly reduce the length of time during which the upper lakes discharged by way of the Nipissing-Mattawa river, though probably leaving time enough for the waters from these lakes to produce all the erosion features found in this ancient stream channel. This would still leave the Eddy basin to be accounted for, a difficulty which may perhaps be diminished by assuming that the second of

the ancient falls was situated at the point where the gorge contracts to the width of the narrower channel of the whirlpool rapids.

It will thus be seen that this interesting problem of the origin of the gorge of the whirlpool rapids, propounded nearly 20 years ago by Dr Pohlman, is by no means wholly solved. We may return to the original solution of the propounder of the question or we may find new evidence which will corroborate Taylor's explanation. And who shall say that still other explanations of these features may not be forthcoming in the future, when those now demanding attention will be no longer regarded as plausible or sufficient?

The upper gorge and the falls

PLATES 1, 2, 4, 5, 11

Whatever may be believed with reference to the narrow gorge of the whirlpool rapids, most observers agree that the broad and deep gorge from Clifton to the present falls was made by a cataract carrying the full supply of water. This, the latest and most readily interpreted part of the gorge, has come to an end at the Horseshoe falls of today, and the character of the channel hereafter to be made can only be conjectured. The river has reached another of its critical points, where a rectangular turn is made, and it is not improbable that, as at the other turns, so here the character of the gorge will change. Already a short channel, considerably narrower than that of the last preceding portion, has been cut by the Horseshoe falls. (Fig. 19) This narrowness of the channel is due to the concentration of the water at the center of the stream. It is easy to see that Goat island and the other islands owe their existence to this concentration of the water; for at one time, as shown by the shell-bearing gravels, these islands were under water. The channel above the Horseshoe falls has been cut more than 50 feet below the summit of Goat island at the falls, while the upper end of the island is still at the level of the water in the river.

Goat island lies on one side of the main mass of forward rushing water, which passes it and strikes the Canadian bank, from which it is deflected toward the center of the cataract, which portion is thus deepened and worn back most rapidly. The directions of the cur-

Plate 11

The Horseshoe falls with Goat island and the Three Sisters, as seen from the Canadian side. This view illustrates the narrowness of the gorge now forming.

rents may be seen from the upper walks in the Canadian park, and the effectual erosion of the banks may also be observed. In many cases the shores have been ballasted and otherwise protected against the current. During an earlier period, when the falls were situated farther north, and before the central part of the stream had been deepened to its present extent, the water, then at the level of the river above Goat island, flooded what is now the Queen Victoria

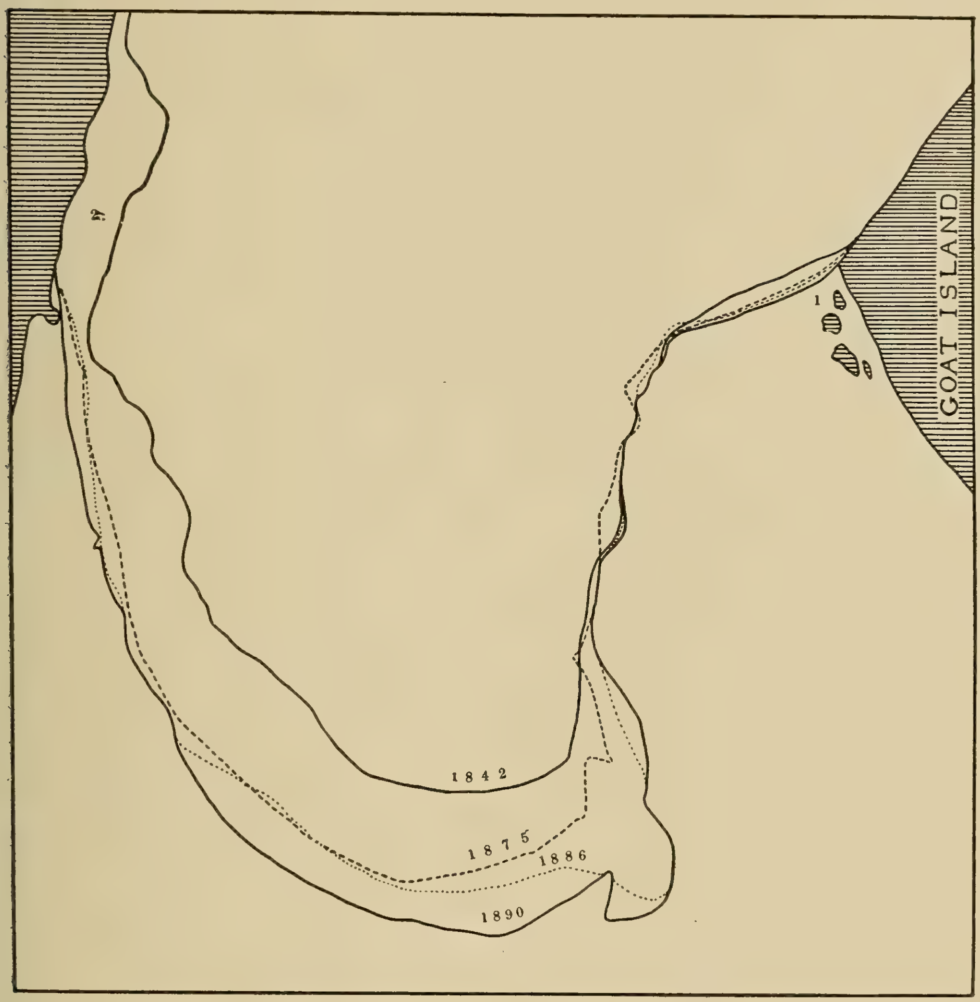

Fig. 19 Crest lines of Horseshoe falls. From the original tracing of the surveys by courtesy of the New York state engineer and surveyor. 1 Terrapin rocks. 2 Former Table rock.

park, and carved from the till the pronounced concave wall which now bounds the park on the west. A local eddy, probably during very recent times, carved the steep and still fresh semicircular cliff which incloses the Dufferin islands.

The fate of Goat island is not difficult to foresee. In a thousand years from now, at the present rate of recession, the Horseshoe falls

will have reached the upper end of the island and will draw off all the waters from the American falls, which by that time will have receded only about half way to the Goat island bridge. All the islands will then be joined by a dry channel to the mainland, an event which was anticipated in the year 1848, when, owing to an ice blockade in the Niagara river near Buffalo, the American fall was deprived of all its waters for a day. As already indicated by Gilbert's forecast, in from two to three thousand years from now, or long before the falls have even reached the head of Grand island, the drainage of the great lakes will be reversed, provided the land continues to rise northward as it has in the past, and Niagara will carry only the drainage of the immediate neighborhood. From a majestic cataract it will dwindle to a few threads of water falling over the great precipice, such as may be seen during the summer season in the upper falls of the Genesee at Rochester.

Age of Niagara

Speculations as to the age of Niagara have been indulged in ever since men began to recognize that the river had carved its own channel. The length of time required for the excavation of Niagara gorge is not merely of local interest but serves as a basis for estimating the length of time since the disappearance of the Laurentian glaciers from this region, and incidentally it has served as a chronometer for approximately measuring the age of the human race on this continent. From insufficient data Sir Charles Lyell estimated the age of Niagara at 36,000 years, while others have assumed an age as high as 100,000 years or more.

No reliable basis for estimating the age of the gorge was known till a series of surveys were made to determine the actual recession of the cataracts. From these the following variable rates of recession of the two falls have been obtained.[1]

[1] Report N. Y. state engineer. 1890.

The American falls

		Feet a year
From 1842 to 1875		.74
1875 " 1886		.11
1886 " 1890		1.65
averaging		
From 1842 to 1890		.64

The Horseshoe falls

From 1842 to 1875		2.01
1875 " 1886		1.86
1886 " 1890		5.01
averaging		
From 1842 to 1890		2.18

This shows a most rapid increase in the rate of recession during the four years between the last two surveys. From this we may assume that the mean recession of a cataract combining the volumes of both American and Horseshoe falls, such as existed throughout the greater period of gorge excavation, is at least three feet a year and may be as high as four or even five feet a year.

The first to make use of this known rate of recession in estimating the age of the gorge was Dr Julius Pohlman. He considered that the gorge of the whirlpool rapids and other portions of the present gorge were of preglacial origin, and so reduced the length of post-glacial time to 3500 years. Since that time numerous estimates of the age of the gorge have been made, the results often varying widely, owing to different interpretations given to the narrow portions of the gorge. It is perfectly evident that, if Niagara was deprived of seven eighths of its water supply, for the period of time during which the gorge of the whirlpool rapids was excavated a very slow rate of recession must have obtained, and hence the age of the gorge is greatly increased. Upham, who does not believe in the withdrawal of the waters, makes the age of the gorge between 5000 and 10,000 years. Spencer and Taylor are ardent advocates of the reduction of the volume of water during a prolonged period, when the supply from the upper Great lakes was cut off.

The former makes the age of the gorge in round numbers 32,000 years, the latter places it tentatively at 50,000 years, though recognizing the uncertainty of many of the elements which enter into his calculations. Prof. G. F. Wright has recently applied a most ingenious method to the solution of this question, and one which seems to eliminate the doubtful factors.[1] This method is based on the measured rate of enlargement of the oldest part of the gorge by atmospheric action. The present width of the river at the mouth of the gorge is 770 feet, and Prof. Wright thinks that it was probably not less at the time when the formation of the gorge began. Assuming that the bank at that time was vertical, he finds that since then the stratum of Lockport limestone at the top has retreated 388 feet. Careful measurements show that the total amount of work accomplished here by the atmosphere since the beginning of gorge formation, was the removal from the side of the gorge of a mass of rock constituting in section an inverted triangle 340 feet high and with a base of 388 feet. This would be similar to a mass with a rectangular section of the same hight but with a base 194 feet wide. The rate of waste of the banks was measured by Prof. Wright as accurately as possible and found to be over one fourth of an inch a year, or a total amount of 610 cubic yards of rock from one mile of the gorge wall. From this he finds that 10,000 years is the maximum amount of time required for the entire change which has occurred in the bank since it was left exposed by the recession of the cataract.

The most recent and most detailed estimates of the age of the gorge have been made by Prof. C. H. Hitchcock.[2] He assumes that the present rate of recession is four feet annually, and finds accordingly that the last formed section of the gorge, from the present falls to the point where it suddenly contracts above the railroad bridges, was formed during 2962 years, which closely agrees with Pohlman's estimate. Thus the beginning of the great cataract at the northern end of the upper great gorge "dates back to 1062 B.C., 300 years before the time of Romulus, or

[1] Pop. sci. monthly. 1899. 55:145-55.

[2] Am. antiq. Jan. 1901.

to the reign of King David at Jerusalem." Prof. Hitchcock believes that the gorge of the whirlpool rapids was formed while Niagara drained only the diminished Lake Erie, and he allows a period of 7800 years for the accomplishment of this task. For the erosion of the remaining portion of the Niagara gorge Prof. Hitchcock allows 8156 years. Thus the total length of time required to carve out the Niagara gorge is considered by Hitchcock to be 18,918 years.

The reader should here be reminded that all such estimates are little more than personal opinions, and that they necessarily vary according to the individual predilections as to greater or less power of erosion possessed by the cataract under the given circumstances. The leading questions concerning the extent of the preglacial erosion in this region, and the changes in volume of water during the lifetime of the Niagara, which are of such vital importance in the solution of this problem, are by no means satisfactorily answered. Nor can we assume that we are familiar with all the factors which enter into the equation. There may be still undiscovered causes which may have operated to lengthen or shorten the lifetime of this great river, just as there may be, and probably are, factors which make any estimates of the future history of the river and cataract little more than a mere speculation. We may perhaps say that our present knowledge leads us to believe that the age of the cataract is probably not less than 10,000 nor more than 50,000 years.

Chapter 3

STRATIGRAPHY OF THE NIAGARA REGION

The stratigraphy of the Niagara region, or the succession of fossiliferous beds, their origin, characteristics and fossil contents, has since the time of Hall's investigations barely received cursory attention from American geologists, whose interest has chiefly centered in the problem of the physical development of the gorge and cataract. A careful examination of the strata of this region and of their fossils reveals problems as interesting and profound as those furnished by the gorge and cataract, and many of them are of far more fundamental and far-reaching significance. Profoundly interesting and instructive as is the "Story of Niagara" and of the physical development of the present surface features, it becomes insignificant when placed by the side of that great history of the rise, development and decline of vast mlutitudes of organic beings which inhabited the ancient seas of this region and whose former existence is scarcely dreamt of by the average visitor to the falls. These ancient hosts left their remains embedded in the rocks of this region; and from the record thus preserved the careful student is able to read at least in outline the successive events in the great drama which was enacted here, in an antiquity so remote that it baffles the imagination which would grasp it. But he who would decipher these records must bear in mind the maxim of La Rochefoucauld: "*Pour bien savoir une chose, il faut en savoir les détails.*" A knowledge of details is necessary to an understanding of the stratigraphic and paleontologic history of this region, and there is no better way of obtaining this knowledge than by a close study of the various sections which expose the strata here described.

The strata of the Niagara region belong to the Siluric series of deposits, which accumulated during the Siluric era of the earth's history.[1] Rocks of Devonic age occupy the southern portion of the district, resting on and concealing the Siluric strata which dip beneath them. (*See* fig. 1, p. 19) As has already been noted, all

[1] *See* table in chapter 2.

Plate 12

Tunnel through Medina sandstone; N. Y. Central railroad cut, looking north. First shanty and remains of first Lewiston suspension bridge are shown.

the rocks of this region have a gentle southward dip, which permits the lower members to appear progressively as we proceed northward over the surface of the old erosion plane. We may now proceed to describe the various members of this series in ascending order.

Oswego sandstone

This, the lowest member of the Siluric, is not exposed in the Niagara region, as its point of outcrop is now covered by the waters of Lake Ontario. (*See* sections 1 and 2, fig. 7) From borings, however, we know its character and thickness, which in this region is 75 feet.

Medina sandstones and shales

Only the upper portion of this formation is exposed in the Niagara district, where the total thickness is more than 1200 feet.

Red Medina shales. The upper beds of this division are the lowest exposed beds in this region. They are bright red sandy shales, generally of a very uniform character, though occasionally a bed which might almost be called a sandstone occurs. Wherever this rock is exposed to the atmosphere, it rapidly breaks down into small angular fragments, which quickly form a debris slope or talus at the foot of every cliff. In the faces of the older cliffs this rock is so friable, that it can readily be removed by the hand, the fragments themselves being easily crushed between the fingers. In the course of time these fragments disintegrate into a fine reddish clay soil, which when wet has a rather tenacious character.

As the lower part of the Niagara river from Lewiston to Lake Ontario is wholly excavated in this rock, it may be seen wherever the banks are kept fresh by the river, or where small lateral streams enter the Niagara. Where erosion is not active, the shale bank is soon reduced to a slope of red clayey soil, which generally becomes covered with vegetation.

A good place for the study of this shale is on the New York side of the Lewiston suspension bridge, where a fresh cut reveals about 50 feet of the rock. The bridge is 65 feet above the river, and the total thickness of red shale above the water at this point is therefore 115 feet. The shale here as elsewhere will be found to be seamed

by whitish or greenish bands, both parallel with and at right angles to the stratification plane. In the latter case they are seen to lie on both sides of a joint fissure, which indicates that the discoloration of the rock, often extending to an inch on either side of the joint, is due to percolating air and water, the latter probably carrying organic acids in solution. The horizontal bands, often several inches in thickness, are probably similarly discolored portions along lines of greater permeability.

No fossils have been found in these shales.

Gray quartzose sandstone. The red shales terminate abruptly and are succeeded by a stratum of gray quartzose sandstone, which is very resistant, and wherever exposed, produces a prominent shelf. This rock varies somewhat in different portions of its exposure, but it averages perhaps 25 feet in thickness. This bed is exposed along the gorge from its mouth to the whirlpool, where it forms a ledge at the water's edge, beyond which it passes below the water level. It is well shown at Niagara glen, where a spring of cool water issues from beneath it, near the water's edge. In the bank on the opposite side, where a fine section of the rocks of the gorge is shown, this quartzose bed is seen in its full thickness, lying between the red shale below and the shales and sandstones above. The red shale at the water's edge has crumbled away, leaving the quartzose bed projecting from the wall in some cases to a considerable extent.

The quartzose sandstone usually forms beds of considerable thickness in this region, though near the top of the stratum a number of thin beds generally occur. The best exposure for the examination of this rock is in the quarries opened up in the terrace on which the Lewiston tower of the suspension bridge stands. In these quarries the sandstone slabs often show smooth surfaces, which generally bear markings similar to those formed by waves on a surface of fine sand. These wave marks are found in most of the sandstones of the Medina group, but they are nowhere in this region so well developed as in the upper thin bedded layers of the quartzose sandstone. No fossils have as yet been found in the gray sandstone on the Niagara river, though farther east a similar quartzose rock shows shells of the Medina Lingula on the surfaces of the layers, which also show wave marks.

The succeeding beds of the Medina as well as the Clinton, Rochester and Lockport beds, are best exposed along the railroad cut of the Lewiston branch of the New York Central and Hudson River railroad. This cut is reached from the Lewiston end through a short tunnel cut in the Medina sandstone (plate 12). As the beds dip southward, and the roadbed rises in the same direction, we pass rapidly across all the formations from the lowest to the highest exposed.

Upper shales and sandstones. The contact between the quartzose sandstone and the overlying Medina shales is not generally well exposed, except in one place. This is in Evan's gully, the first of the small excavations in the roadbed, made by the streams of water which in the spring time cascade from the banks. The quartzose sandstone forms the bed of the gully below the bridge on which the railroad crosses it, and it also forms the capping rock over which the stream cascades to a lower level.

1 The lowest beds of this division of the Medina are gray shales, 25 feet in thickness and readily splitting into thin layers and generally smooth to the touch, indicating the absence of sand. There are however beds of a more sandy character, even to fair sandstones, interbedded with the shales, and this is particularly the case near the middle of this shale mass. These sandstone beds are similar in character to the quartzose sandstone below the shales, but they occur in thin layers, separated by shaly masses. These same beds are exposed in the cutting which leads to the tunnel on the north, where they are shown near the base of the section. They vary in thickness up to 8 inches, and in some cases contain a few fossils, notably the shells of Lingula cuneata (fig. 81). The shales below the sandstone layers are mostly below the level of the roadbed, the greatest thickness exposed above that, being about 6 feet.

The upper 13 or 14 feet of this shaly series are well shown in the cutting north of the tunnel, where they may be seen above the sandstones just alluded to. These rocks present in places an almost perpendicular wall, where the overlying sandstones have not been removed, while from the rapid weathering of the shale, the capping stone generally projects beyond the face of the shale cliff. The un-

dermining of the upper layers thus results in their ultimate breaking down from non-support, and the resulting fall of rocks may be of a dangerous character. Care is therefore necessary in the examination of these sections, and the warnings of the section guards should always be heeded. These men patrol the tracks continually from early morning till after the last train has passed at night. This is necessary, as the fall of rocks is continuous, and often of such amount as to obstruct traffic for some time. Any one who will watch these cliffs for a time from one of the projecting points where a comprehensive view may be obtained, and note the almost incessant fall of rock particles, will receive an impressive object lesson in the processes by which cliff retreat is effected.

In many cases the shale banks are covered with a coating of red mud carried by rains from the red soil above them. This creates the impression that the color of these lower shales is red like that of the shales higher up in the series, and only after breaking off fresh particles can the true color be seen.

2 These gray shales are succeeded by sandstones and sandy shales, some of the former massive, quartzose and in beds 6 or 7 inches in thickness, separated by shaly layers. The sandstone is gray and often porous, as if it had undergone some internal solution, which suggests that fossils may have been present which were dissolved by percolating waters. Fragments of fossils are occasionally found, but mostly in an unidentifiable condition. Many of the thinner and more clayey beds have raised markings on their under side, which may be indicative of the former presence of seaweeds in the muddy beds of this period. Small black phosphatic pebbles, often very smooth, are not uncommon in some of the layers, and larger masses of black, apparently carbonaceous shale are occasionally found mixed with the sand. In the gray shaly sandstone beds the Medina gastropods and bivalves (pelecypods) occur sparingly, and usually in a poor state of preservation. Some of the thin layers are calcareous, though still containing a large proportion of argillaceous matter. These are generally fossiliferous, the most common organism being a small cylindric bryozoan.[1] Fragments of these

[1] Identified provisionally as Helopora fragilis (fig. 74).

beds with the bryozoan weathered out in relief on their surfaces, may be found at the base of the cliff in the cut north of the tunnel.

3 In the northern end of the section the sandstones and sandy shales have a thickness of about 5 feet, and are in turn succeeded by 6 feet of shale, weathering readily into a clayey earth, which accumulates, as a talus on the underlying sandstone ledges. As in the other shale cliffs, so here weathering causes a more rapid retreat of the shale than of the overlying sandstone, which therefore projects beyond the shale cliff till it breaks down.

These shales are mostly gray, sometimes greenish gray, with occasional sandstone bands. Toward the top they become intercalated with reddish bands, and finally the prevailing color of the shale becomes red.

4 Following these shales is a mass of sandstone from 35 to 40 feet thick and consisting mostly of beds which vary from 4 to 6 inches in thickness. The sandstone is compact and solid, reddish in color or gray mottled with red. The beds are separated by red shaly partings, with occasional beds of red shale 2 to 4 feet thick. About 20 feet above the base of this sandstone mass is a concretionary layer from 1 to 2 feet thick, which appears not unlike a bed of large rounded boulders. These concretions vary in size up to 3 or 4 feet in greatest diameter, and they lie in close juxtaposition, not infrequently piled on each other, thus still more simulating the blocks of a boulder bed.

This sandstone cliff is in general quite perpendicular, and the thin and comparatively uniform layers, which are regularly divided by vertical joint fissures, produce the appearance of a vertical wall of masonry, for which many people, seeing it only from the rapidly moving train, have no doubt mistaken it. The regularity of these successive beds is at times interrupted by a heavier layer, either red or gray and mottled, which may be traced for some distance, after which it thins out and disappears. This thinning out of the layers in one or another direction is a common and characteristic feature of these sandstones, and is a direct result of the irregularities of current action during the deposition of the sands. We may trace a sandstone mass for some distance, and then find

that it disappears by thinning, either bringing the layers above and below it in contact or giving way to a bed of shale.

A careful examination of these individual beds will show the presence of ripple marks in many of them. This indicates moderately shallow water during the accumulation of these sands; for ripple marks are found only down to the depth to which wave action penetrates. These ripples vary greatly in size, a bed about 10 feet above the concretionary layer showing examples in which the crests are from one to one and a half or more feet apart.

The fossils found in these sandstones are the characteristic Medina pelecypods, and the common Medina Lingula cuneata.

5 The thin bedded sandstone layers are followed by 12 or 15 feet of massive sandstones in beds from one to several feet in thickness, and varying in color from reddish to grayish. This rock generally shows strongly marked cross-bedding structure on those faces

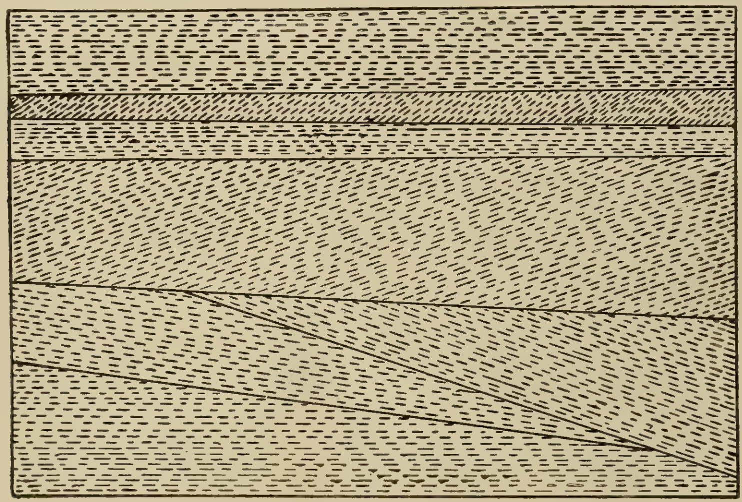

Fig. 20a Cross-bedding in Medina sandstone, Niagara gorge.

which have been exposed for some time. This structure illustrated in figure 20a, copied from a ledge of this rock, indicates diverse current and wave action in the shallow water in which this rock was forming. While the deposition of the strata was essentially horizontal, the minute layers made up of the sand grains were for a time deposited at a high angle, much after the manner of deposition of the layers in a delta. After a while the activity of the current changed to another direction, and the layers already deposited were in part eroded, or beveled across the top, and new layers, inhar-

Plate 13

Section on N. Y. Central railroad cut south of first shanty, looking south. Medina sandstone at base; gray band of upper Medina; Clinton shales and Clinton limestones are shown.

monious with the preceding ones, were laid down on the eroded surface. This was repeated a number of times, as is shown by the succession of changes in the sandstone layers.[1] This structure is sometimes shown on a large scale, as in the case of a bed shown about 200 feet north of " Milk cave ravine ", the second of the small ravines met with in coming from the north. Here some of the layers are very gently inclined, and may be traced for some distance. They are obliquely truncated, other horizontal beds resting on the truncated edges (fig. 20b). (*See also* plate 14)

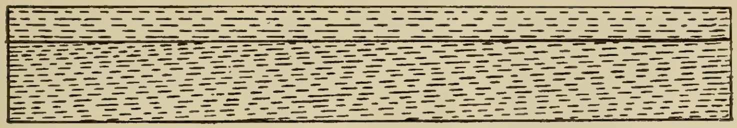

Fig. 20b Contemporaneous erosion and deposition in Medina sandstone, Niagara gorge.

The Medina Lingula (L. c u n e a t a) is found in these sandstones as in the lower ones, but other fossils are rare. Occasionally on the sections the hollows left by the removal of the shells may be seen, while similar cavities, caused by the removal of small black pebbles like those found in the lower layers, also occur. In the upper portions of this mass, on the under side of some thin sandstone lenses resting on and separated by shaly partings, occurs the so-called " jointed seaweed " of the Medina formation, known as A r t h r o p h y c u s h a r l a n i, and illustrated on plate 16. This is a characteristic Medina sandstone fossil, but in this region it has not been found in any of the other sandstone strata. Specimens of this fossil were obtained in digging the great power tunnel at Niagara, but only from the sandstone layers near the bottom of the tunnel, which is about the horizon in which they are found in the gorge section.[2]

6 The highest member of the Medina in this region is a hard, massive bedded and compact quartzose sandstone similar to the

[1] Compare with this the cross-bedding structure shown in the unconsolidated sands and gravels in the Goat island gravel pit, and in the section of the old Iroquois beach at Lewiston.

[2] The restriction of this characteristic Medina fossil to these upper layers of sandstone at Niagara was pointed out to me by John MacCormick, the watchman of this part of the road, who collects these specimens and keeps them for sale. As he is continually handling these rocks and has handled them for years, he has become familiar with their characters, and is therefore in a position to obtain knowledge of such facts.

quartzose bed terminating the lower shales. While nearly white when fresh, this rock generally weathers to a grayish yellow color and often exhibits yellow iron stains. On the weathered edges cross-bedding structure is well brought out. When separated from the rocks below by a shaly bed, this rock generally projects from the bank for a sufficient distance to form a shelter for the watchman in case of a sudden shower. Where this sandstone comes down to the level of the roadbed, at a projecting cusp of the cliff, it has been cut through and a portion of it left between the track and the gorge. In the shadow of this rock mass stands the second of the watchmen's shanties which we meet with in approaching from the mouth of the gorge.[1] The upper quartzose bed has here a thickness of 7½ feet. Several hundred feet south of this point, where the top of this sandstone is level with the roadbed, a huge ripple, 15 feet from crest to crest, and nearly 2 feet deep, is shown on the river side of the track. This "giant ripple" was described and illustrated by Gilbert,[2] who found other ripples of similar size in the Medina sandstone at Lockport, as well as in the quartzose sandstone near Lewiston.

On the surfaces of the flagging stones which are derived from the Medina sandstones, ripple marks of small size are not uncommon, and the sidewalks of Buffalo and other cities where this rock is utilized, often exhibit fine examples of such rippled rock surfaces.

In the cliff of Milk cave falls (or St Patrick's falls), which is the second lateral fall below the mouth of the gorge, the upper beds of the Medina formation are well shown. The concretionary layer is near the level of the roadbed, and has a thickness of 3 feet. 29 feet above it is the base of the upper gray quartzose sandstone, before reaching which we find that the red sandstone gradually loses its bright color, at first being mottled, and then at times losing its red color altogether, though the thin partings of shale still retain

[1] This is occupied by John Garlow, on whose beat most of the "Niagara crinoids" (Caryocrinus ornatus) are to be found. Specimens may generally be obtained from him at a small price.

[2] Bul. geol. soc. Am. 10:135–40, pl. 13, fig. 2.

it. The quartzose capping rock consists at the base of a white bed, from $1\frac{1}{2}$ to 2 feet thick and showing cross-bedding structure, followed by shale 1 to $1\frac{1}{2}$ feet thick and of a reddish color in places, and finally by a solid bed of white quartzose sandstone 5 feet in thickness, and like the lower bed, showing cross-bedding structure on the weathered sections. A few thin layers of sandstone overlie this bed, having a total thickness of less than half a foot. On these follow the shales of the Clinton formation.

The upper Medina sandstones and shales may be traced in both walls of the gorge nearly to the falls. From the southward dip, the beds progressively pass below the water level, till near the falls only a small portion of the upper beds remains. These may be seen at the river margin in the bottom of the gorge, between the *Maid of the Mist* landing and the carriage bridge on both sides of the river. On the New York side only a few feet of the red sandstones are exposed, the remainder being covered by talus. During high stages of the river these exposed beds are covered by the water. On the Canadian side an extensive ledge of the red Medina sandstone is exposed opposite the inclined railway on the New York side. In the banks behind this ledge the white quartzose sandstone which forms the top of the Medina occurs, its top being at least 25 feet above the water level. It here forms a projecting shelf on which rest huge blocks of limestone broken from the cliff above. From this we may judge that at the foot of the Horseshoe falls the upper layers of the Medina may still be above the water level.

Clinton beds

The Clinton beds at Niagara aggregate about 32 feet in thickness and consist of a stratum of shale at the base and two distinct strata of limestone above this. (*See* Plate 14)

Clinton shale. Resting immediately on the quartzose layers which terminate the Medina formation, is a bed of olive green to grayish or sometimes purplish gray shale, which readily splits into very thin layers with smooth surfaces, and is quite soft enough to be easily crumbled between the fingers. Fossils are rare in it, but occasionally layers are found which have their surfaces covered with

crushed valves of small plicated brachiopods, among which Anoplotheca hemispherica and A. plicatula may be mentioned. Other fossils are rarely found except reed-like impressions which are not uncommon. Some impressions have been found which probably belong to Pterinaea emacerata, a pelecypod occurring higher in the Clinton and also in the Rochester shales. The total thickness of these shales is 6 feet.

Clinton lower limestone. On the shale rests a stratum of limestone 14½ or 15 feet in thickness. The lower three or four feet of this rock are compact to granular or finely crystalline, having a sugary texture. Small masses of iron pyrites are not uncommon in this rock, this being the only representative of the ferruginous matter so characteristic of this part of the Clinton beds on the Genesee river and eastward, where a well marked bed of iron ore succeeds the shale. Hall[1] states that "the lower part of the limestone, as it appears on the Niagara river, is highly magnesian, and from the presence of iron pyrites rapidly decomposes, giving rise to the production of sulfate of magnesia, which at favorable points along the overhanging mass upon the river bank, may be collected in quantities of several pounds."

Fossils are not uncommon in this division of the Clinton limestone, though the variety is not very great. The most abundant species are a small brachiopod, Anoplotheca plicatula (fig. 133) with a strongly plicated surface, and a larger flat brachiopod, Stropheodonta profunda, which at times seems scarcely more than an impression on the rock surface. The remaining part of this stratum is a massive dark gray limestone with occasional thin bands of a shaly character separating the individual beds. Recognizable fossils are not very abundant in this rock. Many of the thin bedded portions of the lower Clinton limestone contain numerous shining black phosphatic nodules, very smooth and resembling small black pebbles. These are probably concretionary masses, though some have the aspect of being water-worn organic remains. Where the thin limestone layers are covered with a shaly or sandy coating, impressions of the beautiful, little

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[1]Rep't 4th dist. 1842, p. 63.

Plate 14

View on the N. Y. Central railroad cut, looking south, just south of the second shanty; the third is shown in the distance. The formations shown are, from below upwards: the top of the upper gray band of the Medina; the Clinton shale; Clinton lower and upper limestone; Rochester shale, and, in the distant cliff, the Lockport limestone

branching seaweed, *Bythotrephis gracilis*, may be found. This occurs also on some of the shaly partings of the limestones. The impressions vary from the slender variety of great delicacy to a coarse one in which the frond consists of broad irregular lobes.

This stratum generally forms a vertical wall with the next overlying stratum projecting beyond it.

Clinton upper limestone. In the region of the Genesee river the lower limestone is succeeded by a mass of shale which is generally fossiliferous, and on which lies the upper limestone. In the Niagara region this shale is wholly wanting, the upper limestone resting directly on the lower. The line of separation is however well marked, both by the diverse characters of the two rocks and by the different way in which each resists destruction by atmospheric agencies. The upper stratum is a crystalline and highly fossiliferous limestone, often pinkish in color, though chiefly light gray with yellowish or brownish particles where oxidation has occurred. Portions of the beds consist almost wholly of crinoid stems or joints, which give the rock a coarsely crystalline and sometimes porous aspect. Fossils are abundant in this rock, though the variety is generally not large. The most common species is a rotund variety of the brachiopod, *Atrypa reticularis* (fig. 112), which is generally very robust and sometimes almost globular in form. Of the other fossils in this rock several Stropheodontas may be mentioned, among them *Stropheodonta profunda*. A number of rhynchonelloid shells occur, readily recognized by their pointed beaks and strong plications. Among these are some small specimens of *Camarotoechia acinus*, a species characteristic of the Niagara beds of the west. It is readily recognized by its smooth umbonal area, and its single plication in the mesial depression or sinus, corresponding to which, on the opposite valve occur two plications. Among the more abundant fossils of this rock are smooth elongate and rather strongly biconvex brachiopods of the genus *Whitfieldella*. The most common is W. *intermedia*, but other species occur as well. The thickness of this stratum is 11 feet. The upper beds of this series contain species which on the whole are of a strongly marked Niagaran

type, such as Spirifer niagarensis and others. A common brachiopod is Strophonella patenta, a flat, thin, subsemicircular shell with a straight hinge line and fine surface striations.

A characteristic feature of this upper limestone stratum is the strong development of stylolite structures. These stylolites are vertically striated columns, from a fragment of an inch to several inches in length, and ranged on either side of a horizontal suture or fissure plane in the limestone bed. Projecting from both upper and lower beds, they interlock with each other and so produce a strongly marked irregular suture. This structure is characteristic of limestone beds of this type, but its origin is still obscure. Pressure of superincumbent layers of rock seems to have been the chief cause of their production, this pressure acting unequally on the rock mass, from the presence of fossils or from other causes. A characteristic feature is the open suture at the ends of the columns, which gives the layers the aspect of having separated by shrinkage along an irregular plane. The vertical striations indicate motion either upward or downward.

The Clinton limestones may be seen in both banks of the river where not covered by vegetation, from the mouth of the gorge to within a short distance of the falls, near which they are covered by talus. They always form a cliff in the profile of the gorge, the 6 feet of shale below them forming a sloping talus-covered bank, below which there is another cliff formed by the hard upper Medina sandstone, the lower members forming one or more talus-covered slopes down to the quartzose bed of the Medina. This latter is again a cliff-maker, and generally projects from the bank, while the soft red shale below invariably produces a sloping talus-covered bank. Above the Clinton limestones is another slope and talus formed by the soft Rochester shale, above which a precipitous cliff is formed by the Lockport limestone.

At the base of the cliffs, fallen rocks of the Clinton limestones are mingled with those from the overlying Lockport limestones, and care must be exercised in discriminating between these when collecting fossils. Halfway between the third and fourth watchman's

shanties on the railroad, where the top of the Clinton limestone is on a level with the roadbed, this rock was formerly quarried on the river side, and here a good opportunity is afforded to collect fossils from the limestone fragments. Blocks of the various limestones are also seen by the side of the track between the second and third shanties.

At the whirlpool on the Canadian side the Clinton limestones are seen in both banks of the old St Davids gorge, the section on the west showing glacial striae. Near the foot of the eastern wall of this old gorge and on the talus heaps which flank it, are large masses of calcareous tufa often inclosing leaves, moss or other vegetable structures. These masses appear to come from the horizon of the Clinton limestone, though they have not been seen in place, and it is not improbable that a "petrifying spring" carrying a strong solution of carbonate of lime issues from this rock. Springs issue abundantly from between the two members of the Clinton limestone, and they carry lime in solution, as is indicated by the deposit of soft calcareous ooze on the rocks and other substances over which this water flows. On exposure to the atmosphere this ooze will dry and harden. The joint faces of the Clinton limestone are everywhere veneered over with a thin deposit of calcium carbonate.

Limestone lenses of the Clinton. At intervals in the upper Clinton limestone may be seen large lenticular masses of a compact, hard and apparently structureless limestone, often concretionary and not infrequently showing numerous smooth and striated surfaces of the type known as "slickensides" and which are indicative of shearing movements. One of these masses is visible in the bank opposite the third watchman's hut. Its greatest thickness is about 8 feet, and it lies between the upper limestone and the overlying shale, being partly embedded in both. The rock is often cavernous or geodiferous, the cavities when freshly broken being filled by snowy gypsum or grayish anhydrite. Fossils are abundant in this rock.

Several other lenses of this type are visible in the upper Clinton limestone where it is crossed by the Rome, Watertown and Ogdensburg railroad below Lewiston hights. These masses are however

entirely inclosed by the limestone, from which they are differentiated by their structureless character. The lenses exposed on the Rome, Watertown and Ogdensburg road are rich in shells of orthoceratites and shields of trilobites (Illaenus ioxus), while the lens in the gorge yields chiefly brachiopods, the most abundant of which are the smooth Whitfieldellas, the small W. nitida and the larger W. oblata being the most common.

The following species have been obtained from the lens in the gorge:

Brachiopoda

1 Whitfieldella nitida abundant

2 W. nitida oblata abundant

3 W. intermedia common

4 Atrypa reticularis; specimens with strong, rounded bifurcating striae, noded at intervals by strong concentric striae, and apparently intermediate between the typical form of the species as it occurs in the Clinton and upper limestone and A. nodostriata, the most abundant form of the Rochester shales.

5 Atrypa nodostriata; rather common, convex and more elongate than in the shale above, with the plications generally sharper and bifurcating near the front. The pedicle valve has a distinct sinus bordered by strong plications, the corresponding fold being marked merely by strong plications. Anterior margin distinctly sinuate. The nodulations are not well preserved except in specimens from the shaly portions.

6 Atrypa rugosa; several small specimens, both valves very convex, with strongly defined sinus in pedicle valve, in the center of which is a small plication. Plications bifurcate and also increase by intercalation; crossed by strong rugose lines.

7 Rhynchotreta cuneata americana rare

8 Camarotoechia neglecta rare

9 Anastrophia interplicata rare

10 Spirifer niagarensis; common, large and robust, with long hinge line and moderately high area, and strongly incurved beak. The sinus is flanked by two stronger plications and extends to the beak. The plications are flattened on top.

11 Spirifer radiatus; common but generally crushed; with an extended hinge line and form and proportions similar to the preceding species. The striae are fine and flat on top with very narrow interspaces altogether very similar to those covering the plications of S. niagarensis. A scarcely defined plication appears on each side of the sinus in some specimens, and in these the sinus is rather sharply defined and angular at the bottom. In others the sinus is shallow rounded and not definitely outlined by incipient plications. In the more elongated specimens the cardinal angle is well defined, but in the shorter specimens it is rounded.

12 Spirifer crispus rare

13 Spirifer sulcatus rare

14 Dalmanella elegantula; rare and with greater convexity than that of the specimens in the overlying shale.

15 Plectambonites transversalis rare

16 Leptaena rhomboidalis rare

17 Stropheodonta corrugata rare

18 Orthothetes subplanus rare

19 Strophonella patenta rare

Gastropoda

20 Platyostoma niagarensis rare

Trilobites

21 Illaenus ioxus; fragments of caudal and cephalic shields crowded together into masses sometimes of considerable size.

22 Calymene blumenbachi rare

Bryozoa

23 Lichenalia concentrica; common in very irregular and much distorted masses.

Corals

24 Enterolasma caliculus common

Crinoids

25 Eucalyptocrinus; fragments of root stem and calyx.

In the lenses below Lewiston hights the same species except nos. 2, 3, 9, 10, 14, 15, 17 to 20 and 25 have been found. Rhynchotreta cuneata americana has more the features of the same species from the western Niagara than those of the Rochester shale species.

Spirifer crispus is commonly deficient in plications approaching in this respect and in the character of the sinus, S. eriensis from the Manlius limestone. Atrypa nodostriata is robust, convex, with coarse rounded plications and rather faint concentric striations, characters intermediate between A. reticularis of the Clinton and A. nodostriata of the Rochester shale. Besides these species and some not yet identified, the following occur.

Cephalopoda

26 Orthoceras annulatum

27 O. medullare (?) rare

28 O. sp.

Pelecypoda

29 Modiolopsis cf. subalatus?

The origin of these lenses is still obscure. Many of the fossils found in them are characteristic of the Niagara group of the west, but are rare or wanting in the Niagaran of New York. This is specially the case with the trilobites (Illaenus ioxus) and the cephalopoda. Dr E. N. S. Ringueberg many years ago studied these limestone masses as exposed at Lockport and other more eastern localities, and he termed them the "Niagara transition group".[1] He found in this rock 32 Niagara species, 11 species common to the Clinton and Niagara, two species found otherwise only in the Clinton, and two species not found outside of this rock. The origin and significance of these unique deposits are being carefully studied by the state paleontologist.

Rochester shale

The Rochester (Niagara) shale has a total thickness of about 68 feet in the gorge of the Niagara. It is here divisible into a lower and an upper half. The lower portion is a highly fossiliferous shale with numerous limestone bands, and terminates in a series of thin calcareous beds with shaly partings in all about 4 feet thick, and extremely rich in bryozoa. The upper 34 feet are quite barren and have few limestone layers.

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[1]Am. nat. 1882. 6:711-15.

Plate 15

View of the New York bank a short distance north of the Devil's hole. The gorge-road is shown below, and the New York Central railroad cut near the middle. The fourth shanty is shown a short distance to the left (north) of the bridge.

Lower shales. The beds immediately succeeding the Clinton limestone are calcareous shales with frequent thin limestone layers. The latter are the most fossiliferous, being in general entirely made up of organic remains. The calcareous beds of the lower 5 or 10 feet are particularly rich in crinoid remains. Chief among these organisms, on account of its abundance and perfection, is the little triangular Stephanocrinus ornatus, which may be found in most of the calcareous layers. Fragments of Eucalyptocrinus are always common, while the characteristic Niagara cystoid Caryocrinus ornatus is also found, though not so abundantly as in the upper part of the lower division. The most abundant brachiopod of the lower shales is Whitfieldella nitida oblata, similar to the specimens found in the limestone lenses. The little Orthis, Dalmanella elegantula, is also common, ranging throughout the lower division of the shales. Spirifer niagarensis is common above the lowest 3 or 4 feet of the shale. Orthothetes subplanus, a large, subsemicircular and nearly flat brachiopod, is abundant in some of the calcareous layers, which at times seem to be composed of it, so thickly are these shells piled one on the other. Atrypa nodostriata is the commonest representative of the genus, the larger A. reticularis, so abundant in the upper Clinton, being comparatively rare and subordinate in development. In the limestone bands A. nodostriata is usually rotund, but in the shaly beds it is most commonly compressed. Trilobites are comparatively rare in these lower shales, though representatives of all the species found in this region have been obtained from them. Bivalve molluscan shells are also uncommon, but the gastropods, Diaphorostoma niagarense and Platyceras are not infrequent.

Some of the calcareous bands are almost barren of organic remains, but in most cases these beds will be found to constitute the chief repositories of the fossils.

Bryozoa beds. A short distance south of the third watchman's hut, the section comes to an end, being for some distance replaced by a soil-covered and more or less wooded bank. Where the section

ends the upper Clinton limestone is only a few feet above the road-bed, and the shale above it is accessible. 29 to 30 feet above the top of the limestone, a group of calcareous beds rich in bryozoa project from the bank, being readily traceable for some distance on account of their compact nature. Their total thickness is about 4 feet, and they consist of numerous thin limestone layers with shale partings of greater or less thickness. On the weathered surfaces of the limestone layers, the bryozoans stand out in relief, and such surfaces will often be found completely covered with these delicate organisms. The cylindric types prevail, but the frondose forms are also common. With them occur brachiopods and other organisms. Slabs of this rock are often found on the talus slopes, and they are among the most attractive objects that meet the collector's eye. The section begins again, after an interruption of perhaps a quarter of a mile, near the old quarry in the Clinton limestone. (Plate 15) Between the river and the railroad are several mounds of shale, which were left in place when the railroad cut was made. These are subject to disintegration, and the fossils in consequence weather out. They may be picked up on these mounds completely weathered out, and often in perfect condition. The best of these mounds is about halfway between the old Clinton limestone quarry and the fourth watchman's hut. Here the top of the mound is on the level of the top of the Bryozoa beds, the whole thickness of which is therefore included in this remaining mass. As these beds are extremely fossiliferous, this mound is a productive hunting ground.[1]

An equally productive locality for weathered-out fossils is the slope of disintegrated shale rising from the Rome, Watertown and Ogdensburg railroad tracks above Lewiston hights. The best hunting ground is in the little gullies made by the rivulets of rain water in the bank. Some glacial till is here mingled with the clay from the decomposed shales, and it requires a little attention to distinguish the two.

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[1] The fossils here obtained are extremely delicate and brittle. They should be placed at once on layers of cotton batting, in a small box and covered with similar material, the box being completely filled. This is the only way in which many of these delicate fossils can be carried away without breaking.

Upper shales. Above the Bryozoan beds the shale is soft, and more evenly and finely laminated, splitting often into thin slabs of moderate size. Hard calcareous beds are generally absent, though occasionally found near the top. The stratification and lamination is much more strongly marked in this than in any other division of this rock. When freshly broken, the shale has a brownish earthy color, which changes to grayish when the rock decomposes to clay. Fossils are rare, those found being seldom well preserved. In most cases the shells are dissolved away, leaving only the impressions of the fossil, which from compression become faint, and are not readily recognized without careful scrutiny. The most common remains found in these rocks are bivalve mollusks (pelecypods) and trilobites. Among the former Pterinaea emacerata is the most abundant, while Dalmanites limulurus is the chief among the trilobites of these beds. Other trilobites also occur in these shales, notably Homalonotus delphinocephalus, as well as a number of brachiopods.

Toward the top fossils become rarer, and finally are wanting altogether. The shale becomes more heavy bedded, and calcareous layers begin to increase. The last 10 feet or more are quite calcareous and compact, and have an irregular fracture. They grade upward into the basal layers of the Lockport (Niagara) limestone.

Lockport (Niagara) limestone

The limestone which succeeds the Rochester or Niagara shales forms the summit rock of the series from the edge of the Niagara escarpment to south of the falls. It consists of a number of distinct strata, of varying characters, most of them very poor in organic remains. The total thickness exposed in the Niagara region is not over 130 feet, but borings show that the thickness of the limestone lying between the Rochester shale and the Salina shales is from 200 to nearly 250 feet. Some of the upper beds of this limestone mass may represent the Guelph dolomite and others may belong to the base of the Salina beds. Nevertheless we may confidently assume that the thickness of the Lockport limestone in this region, is at least 150 feet.

Hydraulic cement beds. 1) The lowest stratum of the series is a hard, compact, bluish gray silicious limestone, weathering whitish on the exposed faces, and breaking into numerous irregular fragments larger near the bottom of the stratum but becoming small, angular and subcubical near the top, where the weathering is similar to that obtaining in the upper parts of the shales. This stratum varies from 7 to 8 feet in thickness being in places divided into two tiers, the upper one, 4 feet thick, appearing as a distinct bed. This weathers to a creamy gray color, and breaks into small angular fragments with no regularity of fracture, and independent of the plane of stratification. On some of the weathered edges of this rock irregular stratification lines are visible, giving the beds the appearance of a fine grained sandstone. Occasionally small geoditic cavities occur lined with dolomite or gypsum. The line of contact between this stratum and the underlying shale is an irregular one, the shale surface having a wavy character.

2) This rock is succeeded by a 4 foot stratum of arenaceous limestone which shows no well marked stratification lines on the weathered surfaces, though in places a distinct cross-bedding structure appears. It peels off in irregular slabs parallel to the cross-section, i. e. at right angles to the stratification plane. Near the top of this stratum are a few thin beds which show the finer stratification structure on the weathered edges, the character of this structure being such as is found in fine grained sandstones.

Both these strata appear to be wholly destitute of fossils. It is not improbable however that the scattered geodes represent the places where corals or crinoids occurred, which have subsequently been altered or dissolved out. Aside from this, there is no evidence that this rock ever was fossiliferous, and it is most probable that it represents the accumulation of fine calcareous mud or sand.

Crinoidal limestone. 3) The compact hydraulic rock is abruptly succeeded by a stratum of highly crystalline limestone, on the weathered surfaces of which joints of crinoid stems and other organisms stand out in relief, particularly in the lower part of the stratum. The rock is entirely composed of fragments of organisms which were ground up and mingled together in great profusion. Oblique

bedding lines may be observed occasionally, indicating that the fragments were subject to wave action. The stratum varies in thickness from 5 to 6 feet, and is occasionally divided by horizontal sutures which show a marked stylolitic structure similar to that found in the crystalline upper Clinton limestone. The contact between this and the underlying stratum is wavy. This rock has been quarried at Lockport under the name of Lockport marble.

Geodiferous limestones. The crinoidal limestone is succeeded by strata all of which are more or less geodiferous, though varying considerably in composition and structure.

4) The rock immediately following on the crinoidal bed is a 4 foot stratum of compact, gray fossiliferous limestone, the fossils being of a fragmentary character. Stratification structure is well marked on the weathered surfaces, specially in some of the lower beds of the stratum. Sometimes there is only one thick bed, at others the stratum consists of a number of thin beds with a heavy one near the center. The thin beds show the stratification structure best, having at the same time a strongly granular character. As the fossils are fragmentary, and only accessible on the weathered surfaces, little is known of the organisms that constitute it. Crinoid joints occur, but they are less characteristic of this than of the lower stratum. Geodes however are not uncommon, the cavities being lined with crystals of pearl spar (dolomite) or filled with masses of snowy gypsum.

5) The fifth stratum of limestone in this series is a finely crystalline magnesian rock, like the others destitute of fossils except in so far as these are represented by geodes. The latter are common and filled with alabaster, or sometimes with massive or crystallized anhydrite. The latter is distinguished from the crystallized gypsum or selenite, which it closely resembles, and which occasionally occurs in the same beds, by the cleavage, which is rectangular and nearly equally perfect in three directions in anhydrite, while it is perfect in one direction only in the selenite.

6) A finely crystalline, somewhat concretionary dolomitic limestone, 3 feet thick, next succeeds, the weathered sectional surfaces of which, buff in color, show the fine stratification structure, which

is of the type of the cross-bedding structure in sandstone. Such structure indicates that the bed possessing it was a fine calcareous sand, subject to shifting movements by waves and deposited in moderately shallow water. We need look for organic remains in such a rock with no more assurance of finding them than we bring to the examination of uniform bedded shales. They may be abundant or they may be rare or absent altogether. Thus a limestone need not be necessarily a fossiliferous rock.

Geodes of the usual type are common, the dolomitic lining predominating.

7) On the preceding thin stratum follows a limestone mass of very uniform character, hardly separable into district strata, though consisting of numerous beds.[1] 27 feet of this stratum are shown at the quarry near the northern end of the section, where the upper exposed bed forms the surface rock of the plateau above. The beds are generally of considerable thickness, but the fine stratification structure is not so well marked as in the strata below. The rock may be considered a compact granular dolomite, in which considerable change has taken place since its original deposition. It is of a grayish color but weathers to a lighter tint. Geodes are plentiful, often quite large, and in these, minerals of great beauty are not infrequently found. The most common are the snowy variety of gypsum or alabaster, the darker gray, massive, fine anhydrite and the uniform, fine, dolomite rhombohedra with curved faces, generally of a pinkish tint and familiarly known as pearl spar. Long slender crystals of calcite, generally in the form known as scalenohedra, or dogtooth spar, are not uncommon. These are commonly of a golden color, and large enough to show well their crystal faces. In the new power tunnel which was excavated in the neighborhood of the falls, large masses of transparent gypsum of the selenite variety were found in cavities in this rock. Some of these pieces were 6 inches in length. Masses of limestone lined with pinkish dolomite crystals and occasional large masses of silvery selenite, and set with

[1]The distinction between stratum and bed is an important one. A stratum is a rock mass having throughout the same lithic character, and may be thick or thin. A bed, on the other hand, is that portion of a stratum limited by horizontal separation planes. *See* Geology and paleontology of Eighteen Mile creek pt 1. Introduction.

amber crystals of calcite, were also found in these cavities, the combination being such as to produce specimens of great beauty. Among the rarer minerals found in this rock is the crystallized and cleavable anhydrite, which like gypsum is a sulfate of calcium, but without the water which is characteristic of that mineral. Anhydrite crystallizes in the orthorhombic system, and its cleavage is in three directions, at right angles to each other (pinacoidal), thus yielding rectangular fragments and enabling one to distinguish it from selenite with little difficulty. It is also a trifle harder than selenite which is easily scratched with the finger nail. This form of anhydrite is rather rare, the principal localities for it being foreign. Masses of considerable size have been found in the limestone of this quarry, and small pieces are not uncommon in the geodes of these strata. Both selenite and the cleavable anhydrite are commonly called "mica" by the uninitiated; that mineral however does not occur at Niagara. Small masses of fibrous gypsum or satin spar have been found, but these are very rare. The satin spar of which the cheap jewelry sold in the curiosity shops is made is not from Niagara.

Among the metallic minerals found in this rock, zinc blende or sphalerite is most common. It is generally of a yellowish or light brownish color and brilliant resinous luster. Large masses however are rare. Galenite or lead sulfid crystals are also occasionally found, but this mineral is comparatively rare. In addition to these, iron pyrite, iron-copper pyrite (chalcopyrite), green copper carbonate (malachite), fluor spar (fluorite), iron carbonate or brown spar (siderite, generally ferruginous dolomite), strontium sulfate (celestite) and native sulfur as well as other minerals are met with.

The total thickness of the limestone exposed in this section is thus somewhat more than 55 feet. At Lewiston hights, on the edge of the escarpment, only about 20 feet are exposed. This includes the two lower strata of hydraulic limestone, the crinoidal limestone and a few feet of the lowest geodiferous beds (stratum 4). Over this lie some two or three feet of glacial till. The distance between the edge of the escarpment and the quarry at the end of the section, is a little over a mile and a half, the increase in thickness of the

limestone and the rate of dip (since the surface is about level) is therefore a trifle less than 25 feet in the mile.

The crinoidal limestone is the most prominent stratum on the edge of the escarpment. From its base springs of cold and clear water issue at numerous places along the outcrops, both on the edge of the escarpment and in the gorge. The most prominent of these is at the head of " Milk cave " or St Patrick's falls, and here as almost everywhere at the base of the crinoidal limestone, shallow caverns abound. One of these caverns near the head of the falls, has a depth of 35 or 40 feet and is high enough to permit one to walk upright. No stalactites are found in these caverns, but the walls are much disintegrated and in places covered with a fine residual sand.

In the fields above this cavern are several sink holes of moderate depth, which serve as catchment basins for the waters of the surrounding country, which issue from these caverns during the wet seasons.

The cavern known as the Devil's hole belongs to this category. As in the other caverns, the roof is formed by the crystalline crinoidal limestone (stratum 3), the cavern itself being hollowed out in the hydraulic cement rock. This cavern is deeper than most others, and at the end a spring of deliciously cool water issues from between the two beds, the upper " spring line " of this region. There is no evidence that the cavern extended any deeper than it does at present, nevertheless the spot is worth visiting, as it is the only accessible one of the numerous springs and caverns. The fall of the Bloody run at this place is over a thickness of almost 60 feet of limestone, and the chasm which this stream has worn is interesting both from its historic and scenic points of view.[1]

West of the Niagara river on Queenston hights several quarries have been opened in these limestones, some distance south of the edge of the escarpment. The rock quarried is the crinoidal limestone and overlying beds. The total depth of rock in the quarry is 27 feet, of which the lower 14 or 15 feet are bluish gray and the upper of a lighter gray color. The limestone is here much more uniform, crystalline throughout and more fossiliferous. This may

[1] *See* brief mention of Bloody run massacre in Introduction.

indicate a nearness to the reef of growing organisms which supplied the material for these beds. Geodes lined with dolomite crystals occur in this rock, though not so plentifully as at the quarry in the gorge. Below the crystalline limestone is found the cement rock, which is from 4 to 10 feet thick and is quarried in a tunnel under the limestone quarry.

Owing to the resistant character, the limestone is everywhere exposed in the gorge, forming cliffs which are almost invariably perpendicular. Large blocks of this rock cover the talus everywhere, one of the largest of these being " Giant rock " along the gorge road. This is a block of the upper geodiferous limestone which has fallen from above, and now lies with its stratification planes at an angle of about 45°.

The limestones are well exposed along the gorge road, south of the railroad bridges, but without a special permit no one is allowed to walk on this roadbed. The contact between the limestone and the shale is here very irregular, indications of erosion of the shale prior to the deposition of the limestone occurring. The limestone is also somewhat concretionary, rounded masses projecting down into the shales. The succession of strata is here as follows:

1 Concretionary, irregularly bedded gypsiferous limestone, often earthy and with occasional thin, shaly layers; it splits readily into slabs perpendicular to the stratification. Thickness 6-8 feet.

2 Fine grained limestone with sandy feel, sometimes massive, sometimes in shattered layers with earthy or shaly partings, and separated from the underlying rock by an earthy layer. It weathers to an ashy or sometimes an ochery color, and varies somewhat in thickness. The upper layer is however a solid and fine grained limestone. Thickness 4-4.5 feet.

Strata 1 and 2 are the equivalent of the cement beds.

3 Crystalline and crinoidal limestone abruptly succeeding the lower bed. It is massive though somewhat thin bedded and contains geoditic cavities filled with gypsum. This continues uniform for a thickness of about 19 feet.

4 Compact limestone; concretionary with cavities containing gypsum and other minerals, and with sphalerite embedded in the rock.

The bedding and upper contact lines are irregular. Thickness 14-15 feet.

5 Compact, finely crystalline and homogeneous dolomitic rock, showing traces of fossils and slickensides. Beds showing Stromatopora common. In places the rock has a porous appearance and is rich in geoditic cavities, which are lined with dolomite and calcite crystals. Thickness 19 feet.

This stratum forms the lower portion of the cliff at the first cut on the gorge road, and the basal part of the mass left standing on the river side. Heads of Stromatopora may be seen in this rock, some of the geoditic cavities having replaced this fossil. This is about the summit of the beds exposed in the quarry at the end of the railroad section.

6 Earthy, compact dolomite in thin layers, which give the cliff the appearance of a stone wall. Toward the top the rock becomes more compact and heavy bedded, this giving the appearance of an overlying stratum. This rock is full of geodes lined with pearl spar or dolomite, the cavities ranging in size up to that of a fist or larger. The beds are generally less than a foot in thickness, the average being from 3 to 6 inches. Toward the top of the cut, the rock becomes more compact and finely crystalline, but otherwise remains similar. Pearl spar geodes remain common to the top. The thickness of this mass, at the beginning of the gorge road, is about 45 feet.

The total thickness of the limestone exposed on the gorge road is in the neighborhood of 110 feet. This is double the thickness found at the quarry, the distance between the two points in a straight line being about three miles or nearly four following the curvature of the river. The rate of increase in thickness, or the amount of dip of the strata is therefore about 20 feet to the mile.

Almost the only recognizable fossils found in these limestones, excepting the crinoid fragments, are the hydro-coralline Stromatopora (concentrica Hall) and the coral Favosites. Both occur in the middle and upper portions of the exposed mass, and may generally be seen in the weathered upper surfaces of the limestone beds. Thus wherever these beds are exposed on the sur-

face, as at the whirlpool on the Canadian side, at the fall of Muddy brook, and near Clifton, these fossils are generally weathered out in relief. They are however not readily separated from the rock. Many of the geodes still show traces of coral structure, which is sometimes shown in the included gypsum.

The limestone is well exposed in the cliff at Goat island, where it has a total thickness of about 110 feet. The contact between the shale and limestone can be seen near the entrance to the Cave of the Winds, where it is about a foot above the top of the stairs. The roof of the Cave of the Winds is formed by the crystalline crinoidal limestone, the same bed which forms the roofs of all the minor caverns along the gorge. The cement beds, about 10 feet thick, together with the 70 feet of Rochester shale, are removed by the spray to a depth of perhaps 30 or 40 feet, the floor of the cave being probably on the upper Clinton limestone, thus making the hight of the cavern 80 feet. Floored and roofed by resisting beds of crystalline limestone, this great cavern is a fit illustration of selective erosion by falling water on rocks of unequal hardness.

The massive limestone which forms the vertical cliff of Goat island is 68 feet thick, its base being on a level with the foot of the Biddle stairway. The top of this cliff marks approximately the level of the falls on either side of Goat island, which therefore have a total thickness of nearly 80 feet of limestone, of which however the lowest 10 feet yield to erosion as does the underlying shale. We may thus say that at the falls there are 70 feet of resistant limestone on top, and 80 feet of yielding shales and limestones below. As the crest of the falls approximates 160 feet above the river below, at least 10 feet of Clinton limestone are found above the water level.

From the top of the vertical cliff at Goat island a sloping bank exposing thin bedded limestones, overlaid by about 10 feet of shell-bearing gravels, rises to a hight of about 40 feet, while on either side of Goat island these thin bedded limestones form the rapids above the two falls. As the total hight of the rapids is about 50 feet, and, as they are formed along the strike of the beds owing to the right-angled turn in the river at this point, the thickness to be added to the known limestone mass is not over 50 feet, giving a total thickness of 130 feet of limestone exposed within this region.

Guelph dolomite

This rock, named from its occurrence at Guelph (Ont.) about 75 miles northwest of Niagara falls, is, so far as known, absent from the Niagara district. As before noted, it may however be represented in the buried hundred feet of limestone (more or less) which lie above the 130 feet of known rock, as shown by the borings in this region.

Salina beds

The basal beds of the Upper Siluric are the saliferous shales and calcareous beds of the Salina stage, so named from the salt-producing village of Salina in Onondaga county. This is the horizon which furnishes all the salt, as well as the gypsum of New York state and the adjoining territory. In the Niagara region this formation is not well exposed, owing to the soft character of the rock which has permitted deep erosion in preglacial times, and to the extensive drift deposits which cover it. The only known exposures on the Niagara are on Grand island and on the Canadian side of the river opposite North Buffalo. On Grand island the Salina rocks may be seen at Edgewater about 200 yards below the boat landing. Here the following section is exposed.[1]

3 Light colored, soft, friable gypseous shales, 5 feet
2 Greenish shales containing nodules of gypsum, 1½ feet
1 Black shale in the river bed

The exposure extends 300 yards down the river bank.

At the extreme northern end of the island, where it divides the river, an impure, thin bedded limestone of this series is exposed. The exposures on the Canadian bank begin a short distance south of this, and extend to the International bridge, the rock here being a more or less gypsiferous shale.

From the numerous borings in this region we have however gained a fair knowledge of the character and thickness of this rock, the latter averaging, according to Bishop, 386 feet. The best available record of the rocks lying between the Waterlime and the Niagara series of limestones is the core of a well drilled on the land of the Buffalo cement co. in North Buffalo. This core, which has a

[1] Bishop. 15th an. rep't N. Y. state geologist. 1895. p. 311.

length of 1305 feet, is now preserved in the museum of the Buffalo society of natural sciences, and from it the following succession of strata can be demonstrated.[1]

		Feet
Rondout waterlime	Waterlime above the mouth of the well, about	7
	Shale and cement rock in thin streaks	25
	Tolerably pure cement rock	5
	Shale and cement rock in thin streaks	13
Salina	Pure white gypsum	4
	Shale	2
	White gypsum	12
	Shale	1
	White gypsum	4
	Shale and gypsum mottled	7
	Drab colored shale with several thin layers of white gypsum	58
	Dark colored limestone	2
	Shale and limestone	4
	Compact shale	3
	Gypsum and shale mottled and in streaks approximating	290±

The gypsum of this formation has never been mined in this district, owing to the strong flow of water through these strata. No salt beds are found in the Salina of this region, though they are characteristic of the formation farther east. Salt water is however obtained. Fossils are very rare throughout these beds; none have been found in the exposures on the Niagara river.

Rondout waterlime

The Salina beds of this region grade upward into a magnesian limestone which contains a considerable amount of aluminium silicate. The upper portion of this series, which in the Niagara region has a thickness of about 50 feet, is very uniform in character and suitable for the manufacture of hydraulic cement. In North Buffalo, extensive quarries have been opened in this rock by the Buffalo

[1] Pohlman. Cement and gypsum deposits in Buffalo. Am. inst. min. eng. Trans. Oct. 1888.

cement co., and here a stratum nearly 6 feet thick is quarried and converted into cement. As the quarries are opened south of the second escarpment (inface of the Onondaga cuesta[1]), the surface rock of Onondaga limestone and the Manlius limestone have to be stripped off before the cement rock is reached.

The characters of the several strata have been briefly enumerated in the section derived from the gas well core. The upper beds, which are alone accessible in this region, may generally be seen in the escarpment, specially where it is crossed by streams, as at Williamsville, or where quarries have been opened. The rock is fine grained, often showing a marked banding or lamination, and breaks with a conchoidal fracture, producing rounded surfaces.

In this rock we find entombed the remains of those remarkable crustacea, the Eurypterids, whose bizarre form, remotely fish-like, has excited more interest than any other fossil found in this region. These Crustacea have made the Waterlime of Buffalo famous, and the Buffalo society of natural sciences, whose collections embrace a magnificent series of these fossils, has fittingly adopted it as chief among its insignia.

Besides these crustacea several other organisms have been found in the Waterlime strata of north Buffalo. Among these are a number of undescribed brachiopods, including at least one species of Lingula.

Manlius limestone

The waterlime of north Buffalo is succeeded by a stratum of impure limestone from 7 to 8 feet in thickness and known locally by the name of " bullhead " rock. The line of demarkation between the two formations is not a very pronounced one, for the inferior rock grades upward into the superior one. The rock is a dolomitic limestone of a very compact semicrystalline character, with a high percent of argillaceous material, and not infrequently a strong petroleum odor. It is mottled, having frequently the appearance of a limestone breccia, and consists of purplish gray, angular or rectangular pieces and similar light colored and more yellowish ones. The latter appear to be more argillaceous than the former. There

[1] *See* chapter 1.

is no conclusive evidence that the rock is brecciated, nevertheless the coloration strongly suggests it.

This rock is commonly very porous in its upper portion, the cavities being often lined with crystals of calcite or other minerals. The smaller of the cavities are due to the dissolving out of the small coral, Cyathophyllum hydraulicum, which was exceedingly abundant in the upper part of the stratum. This coral is generally found in a prostrate position, with the mold perfectly preserved in the inclosing rock matrix, so that a perfect cast of the coral can be obtained by the use of gutta percha or dentist's wax. The best exposure of this rock is in the walls of the quarries of the Buffalo cement co. It may also be seen in the face of the Onondaga escarpment at Williamsville and eastward. In many places in the cement quarries, the upper part of this limestone is rich in iron pyrites, which commonly occurs in small cubes, not infrequently oxidized to limonite. Green stains of hydrous carbonate of copper, or malachite, are not uncommon, these resulting probably from the decomposition of chalcopyrite, which is disseminated in minute grains through portions of the rock. Many of the geode cavities contain scalenohedra or acute rhombohedra of calcite, as well as sulfate of strontian.

A remarkable feature of the Manlius limestone of the Niagara region is the nature of the fossil fauna which it contains. This fauna shows an intimate relation to the Coralline limestone fauna of Schoharie county (N. Y.) a rock which is regarded the eastern equivalent of the Lockport (Niagara) limestone of this region. Several of the species found in the Manlius limestone of this region are identical with those of the Coralline limestone, while between other representative species of the two formations there exists a very close relationship. It is difficult to escape the conclusion that the Manlius limestone fauna of the Niagara region is a late return of the Coralline limestone fauna, at the close of the long interval during which the Salina shales were deposited in the Siluric seas of this region.

The Siluro-Devonic contact

The Manlius limestone of the Niagara region is succeeded by the Onondaga limestone of Devonic age. The latter rests unconform-

ably on the former, this unconformity being emphasized by the absence of all Lower Devonic strata in this region, with the exception of thin lenses of sandstone which may be correlated with the Oriskany. The upper surface of the Manlius limestone is knotty and concretionary, producing minor irregularities, but in addition to these there are well marked traces of the erosion of these strata, prior to the deposition of the overlying beds. These traces are of the nature of channels and irregular truncations of the strata, the former in some cases assuming considerable importance. (Fig. 21-23) In the east wall of the quarry, not far from the stamp mill, the surface of the Manlius limestone is strongly excavated, the excavation being mainly filled by beds of the Onondaga limestone. Between the two limestones occurs a mass of shale and conglomerate having a total thickness, in the central portion, of something over a foot. The lower 6 or 8 inches are a limestone conglomerate, the pebbles of which are fragments of the underlying limestones. These pebbles are flat, but well rounded on the margins, showing evidence of protracted wear. They are firmly embedded in a matrix of indurated quartz sand, which surrounds them and fills in all the interstices. This bed thins out toward the sides of the channel. On the conglomerate lie about 6 inches of shale and shaly limestone, and these are succeeded by the Onondaga limestone. The width of the channel, which is clearly an erosion channel, is about 18 feet, and its depth is about $3\frac{1}{2}$ feet. (Fig. 23)

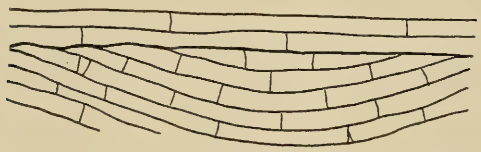

Fig. 21 Unconformable contact between Manlius and Onondaga limestones, Buffalo cement quarry.

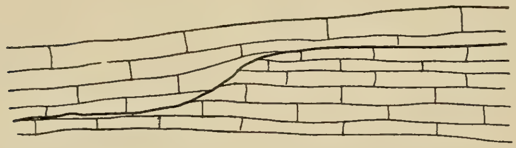

Fig. 22 Erosion of Manlius limestone prior to deposition of Onondaga limestone, Buffalo cement quarry.

From the point where this channel is seen, the contact can be traced continuously for a thousand feet or more eastward, along the quarry wall. It frequently shows a thin shaly bed, often containing quartz grains, lying between the two limestones.

Not very far from the channel just described, a remarkable "sandstone dike" penetrates the Siluric limestones of the quarry wall.

This dike, which can be clearly traced in the wall of the quarry for a distance of perhaps 30 feet in an east and west direction, was

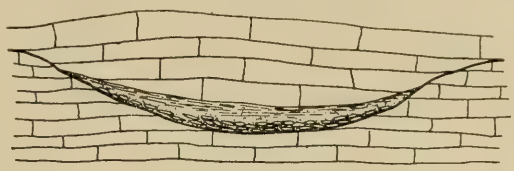

Fig. 23 Channel in Manlius limestone with Oriskany sandstone and conglomerate layers, capped by Onondaga limestone, Buffalo cement quarry.

caused by the filling of an ancient fissure in the Siluric strata, by sands forcibly injected from above. The fissure had a total depth of about 10 feet; its walls were very irregular, and at intervals lateral fissures extended in both directions. (*See* Fig. 24) All of these are now filled with pure quartz sand, firmly united into a quartzose sandstone by the deposition of additional silica in the interstices between the sand grains.

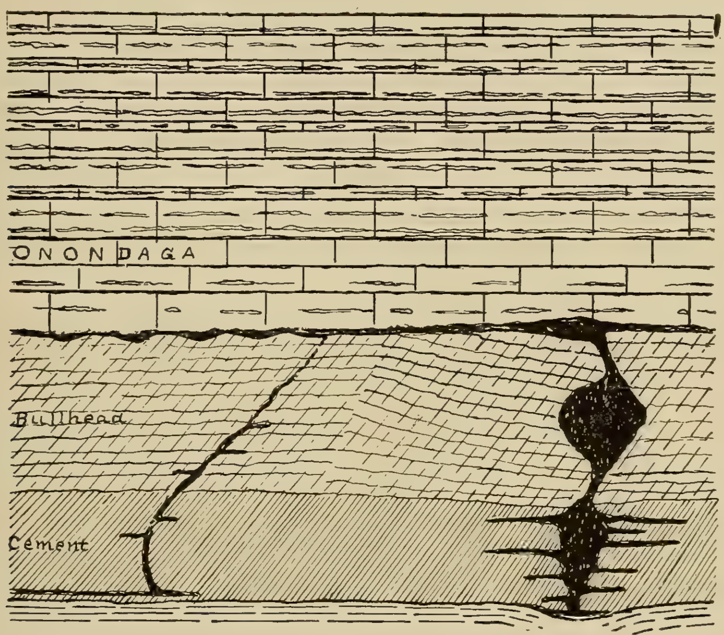

Fig. 24 Sandstone dike in the Siluric strata of the Buffalo cement quarries. (After Clarke)

The dike penetrates the "bullhead" rock and enters the waterlime to a depth of from 2 to 3 feet. It is squarely cut off at the top, where the Onondaga limestone rests on its truncated end and on the limestone flanking it. The Onondaga limestone is entirely unaffected by the dike, being evidently deposited after the formation and truncation of this remarkable mass of sandstone. The width of

the filled fissure is scarcely anywhere over 2 feet, but the lateral offshoots extend many feet into the walls of Manlius limestone. These offshoots or rootlets of the dike are irregular, commonly narrow, and often appear as isolated quartz masses in the Manlius or the waterlime rock, the connection with the main dike not being always discernible. Such masses of quartz sandstone have been traced for more than 30 feet from the dike. The irregularity of the walls of the fissure is very pronounced. Angular masses of limestone project into the quartz rock, while narrow tongues of sandstone everywhere enter the limestone. Extensive brecciation of the limestone has occurred along the margin, and the sandstone there is filled with angular fragments of the limestone, which show no traces of solution or wear by running water. These limestone fragments are themselves frequently injected with tongues of the quartz sand. Microscopic examination shows evidence of a certain amount of shearing along the margin of the dike, accompanied by a pulverizing or trituration of the limestone, and followed by reconsolidation. These and other features point to a cataclysmic origin of the fissure which contains the dike and a more or less violent injection of the sand. The fissure must have been formed and filled before the deposition of the Onondaga limestone and while the Manlius limestone was covered by a stratum of unconsolidated sand. The formation of the fissure and the injection of the sand into it from above must have occurred simultaneously; for this appears the only way to account for the inclusion of large fragments, or "horses", of the wall rock in the loose sand, and the injection of the sand into all the cracks and crevices. It seems probable that the fissure records an earthquake shock during the period intervening between the close of the Siluric age and the deposition of the Devonic limestones. This is borne out by the occurrence of numerous small faults or displacements in the underlying strata of waterlime.

Devonic strata

The Lower Devonic is represented in the Niagara region by the thin beds of shale and sandstone before mentioned as occupying erosion hollows in the Manlius limestone. These are perhaps the

equivalent of the Oriskany sandstone of eastern New York, though no fossils have been found in them. With the exception of these layers the Lower Devonic strata are wanting in this region.

The Middle Devonic is however well represented in the Niagara region by the Onondaga limestone. This rock, which, as has been shown, rests in most cases directly on the Manlius limestone, consists of a lower crystalline and highly fossiliferous portion, and an upper mass full of layers of hornstone or chert which on weathered surfaces stand out in relief. This part of the formation is generally known as the Corniferous limestone, in reference to the layers of chert which make the rock unfit for other use than rough building. Owing to the presence of the hornstone, this rock effectually resists the attacks of the atmosphere, and hence its line of outcrop is generally marked by a prominent topographic relief feature, the second escarpment of western New York i. e. the inface of the Onondaga cuesta.

The chert-free lower member of this formation varies greatly in thickness even within a limited territory. It is in places extremely rich in corals, and outcrops of this rock show all the characteristics of an ancient coral reef.

History of the Niagara region during Siluric time

We have now gathered data for a brief synopsis of the history of this region during Siluric time. Much still remains to be learned, but from what is known we can trace at least in outline the sequence of geologic events which characterized that ancient era of the earth's history in this vicinity.

When the Siluric era opened, New York, with portions of Pennsylvania and southern Ontario, was covered by the shallow Medina sea. This sea appears to have been of the nature of a mediterranean body of water, which later changed to a bay opening toward the southwest. This "Bay of New York", as we shall call it, came into existence by the orogenic disturbances which marked the transition from the Ordovicic to the Siluric era, and as a result of which the Taconic mountain range, with the Green mountains and the corresponding Canadian ranges, were elevated. This cut off the

communication between the open Atlantic and the interior Paleozoic sea which existed during Ordovicic time. This bay was thus surrounded by old-lands on the north, east and southeast, and its waters appear to have been very shallow. We do not know just what the conditions were under which the early Siluric deposits of this region were made; for the lower beds are so barren of organic remains, that we are forced to look for evidences other than that furnished by fossils, of the physical conditions during this period. It is not improbable that the waters of the early Medina sea were cut off from the ocean at large, at least sufficiently to prevent a free communication. This may not have been the case at first; for Arthrophycus harlani flourished in these waters during the deposition of the Oswego beds,[1] and this species characterizes the rocks of late Medina age, during the deposition of which we have reason to suppose that a junction of the Medina sea with the ocean at large had been effected.

Along the eastern and southeastern margin of this interior water body were deposited the thick beds of conglomerate, which now constitute the capping rock of the Shawangunk and other ranges of hills, while farther west, at a distance from the source of supply, the Oswego sandstone was accumulating. Later the character of the deposit changed in this region, from the gray silicious sands to the impalpable muds and fine sands of the lower Medina. Whatever the source of these sands, ferruginous matter was plentiful, as shown by the red color of the deposits, and this leads to the supposition that they were derived from the crystalline rocks of the Adirondacks and the Canadian highlands and not from Ordovicic or Cambric deposits.

It is not improbable that, during the early Medina epoch, the waters of this basin were of a highly saline character. No deposits of salt were formed, or if these existed, they were subsequently leached out. The Medina beds are however rich in saline waters, salt springs being common throughout this region,[2] and this may

[1] This species is found in the eastern part of the district, at the base of the Oneida conglomerate.

[2] In the early part of the century salt was not infrequently manufactured from these springs.

indicate a high degree of salinity of the waters of the early Medina sea. If such was the case, it may have been accompanied by a more or less arid climate, which favored the concentration of the sea water. Thick beds of terrigenous material accumulated in the center of the Medina basin reaching in the Niagara region a thickness of over a thousand feet. These early deposits probably did not extend far west for, though in northern Ohio and Michigan, Medina beds from 50 to 100 feet or more in thickness are known, these are probably to be correlated with the upper Medina of the Niagara region.

Toward the close of the Medina epoch, the Siluric sea had encroached on the lands to such an extent as to effect a junction with the Medina basin, whereupon normal marine conditions were again established. This is indicated by the marine fauna and flora which characterize the upper Medina beds. The first deposit in this region, on the reestablishment of normal marine conditions, was the white quartzose sandstone which caps the red shale of the lower series. Mud and sand now alternated, indicating an oscillation of conditions with numerous changes in the currents which distributed the detrital material. Thin beds of limestones also formed at rare intervals, chiefly from the growth of bryozoans in favorable localities. In the Bay of New York the waters continued moderately shallow, as shown by the well developed cross-bedding structure in the sandstones. At intervals large tracts seem to have been laid bare on the retreat of the tide, as indicated by the wave marks and other shore features which give the surfaces of some Medina sandstone slabs such a remarkable resemblance to a modern sand beach exposed by the ebbing tide. In fact, we may not inaptly compare this stage of the Siluric bay of New York with the upper end of the modern bay of Fundy, where the red sands and muds are laid bare for miles on the retreat of the tide.

After the last sandstone bed of the Medina stage had been deposited, the water probably became purer and deeper, and the 6 feet of Clinton shales were laid down in the Niagara region. In the eastern part of the Bay of New York, sandstones were deposited even during the Clinton epoch, while the conditions favoring the deposition of limestone existed only during the short interval in

the Niagara period, when the Coralline limestone of Schoharie was laid down. Westward, however, the adjustment of conditions went on more rapidly, and the Clinton limestones, with the calcareous shales and limestones of the upper Niagaran, became the characteristic deposits. During nearly the entire Niagara period life was abundant in the Siluric sea, and the Bay of New York had its marvelous succession of faunas, which have made these strata the standard for the Siluric beds of this continent.

All the Siluric limestones of the Niagara section show characters pointing to a fragmental origin, and in this respect they contrast strongly with the Devonic limestones in the southern part of the district. The latter, as before mentioned, show the characteristics of an ancient coral reef, and we may therefore assume that they were built up in situ by the polyps and other lime-secreting organisms. Not so with the Siluric limestones. These, to be sure, were derived from similar deposits by lime-secreting organisms, but these deposits were originally made in a different place from that in which we find the limestones today. A sedimentary limestone or lime-sandstone is similar to a quartz sandstone or a shale, in that the material of which it is formed is the product of erosion of pre-existing rocks. In the case of the quartz sandstone, this is generally an inorganically formed rock, while the sedimentary limestones are most usually derived from organically formed rocks. In the former case, the source of the material is often a distant one, while in the latter it is generally, though not necessarily always, close at hand. A coral reef growing in moderately shallow water is attacked by the waves, as are all rocks which come within their reach. Erosion results, and the product of this activity is carried away and deposited on the ocean floor as a calcareous sand. Thus stratified deposits of limestones are formed, whereas in the original organic reef, no stratification is to be expected. In the immediate neighborhood of the growing reef, the beds of calcareous sand will slowly envelop the original deposit from which they were derived, and thus the source of supply is chiefly the upper growing portion of the reef. On the lime-sandstone strata which flank the reef, independent masses of coral may at times grow, while other or-

ganisms, such as mollusks and brachiopods, will also find this a convenient resting place. Thus the organically formed limestone masses and the fragmental limestones will interlock and overlap each other around the borders of a growing reef. It follows then that in the neighborhood of the growing coral masses the sands derived from their destruction will be coarser, the finer material being carried farther out to sea, and deposited at a distance from the source. Thus an approximate criterion for the determination of the distance of any given bed of calcareous sand from its place of origin is furnished. If deposits of such calcareous sand are made in shallow water, cross-bedding and ripple marks will be found just as in the quartz sands, and, as we have seen, the former structure is characteristic of most of the strata of Lockport limestone exposed in the gorge section at Niagara. It may be added that, as the organic limestone will continue to form as long as the conditions are favorable, the supply of calcareous sand is practically inexhaustible. Hence thick beds of such lime-sandstones may form.

In the Niagaran seas the chief reef-building corals were Favosites, Halysites and Heliolites, together with the hydro-coralline Stromatopora. Bryozoans also added largely to the supply of organically formed limestone of the various reefs. But perhaps the most important contributors in this connection were the crinoids and related organisms, which may at times have constituted reefs of their own. Their abundance is testified to by the frequent thick beds of limestone, which are almost wholly made up of broken and worn crinoid fragments. The crinoids fell an easy prey to the waves, for, on the death of the animal, the calyx, arms and stem would quickly fall apart into their component sections, and hence yield fragments readily transported by the waves. In the case of the corals and the shells, which latter probably formed no unimportant part of the organic contributions to the reefs, the work of grinding the solid limestone masses into a sand probably required the aid of tools, such as large blocks that could be rolled about by the waves, or it may have been aided by the omnipresent reef-destroying organisms.

The infrequency of exposure of the fossil reefs, which furnished the calcareous sand, need not disturb us. We must remember that

the actually exposed sections of these limestone strata are very few when compared with the great extent of the beds themselves. It must also be borne in mind, that vast portions of these limestone beds have been removed by erosion during the long post-Siluric time. When we realize that the actual reefs must have been widely scattered in the Niagara sea, and that our sections through these strata are random sections, we need feel no surprise at the unsatisfactory character of these exposures. It must however be added that sections farther east, as at Lockport or other localities, generally show much more of the reef character of the deposit, the corals in these being correspondingly abundant. The upper geodiferous beds of the limestone at Niagara were probably much more fossiliferous than the lower. As before mentioned, the geode cavities most likely are the result of alteration or solution of some fossil body, probably a coral. Though fossils may have been plentiful, none of these beds, so far as examined, show the characteristics of true reefs. They have more the aspect of beds of coral sand, on which isolated heads of corals and other organisms grew rather plentifully.

During the dolomitization of these limestone beds, which was probably brought about by chemical substitution before the consolidation of the coral sand, many of the fossils which were included in these sands probably suffered alteration and more or less complete destruction. Thus it will be seen that even the few organisms which were embedded in these coral sands, did not survive the subsequent changes, and thus the barrenness of these great limestone masses appears to be fully accounted for. The fossiliferous character of the upper Clinton limestone, as well as the coarseness of the calcareous fragments of which it is composed, points to a nearness of this rock to the source of the material; for in the vicinity of the coral and crinoid reefs the food supply for other organisms would be most abundant, and hence these would develop most prolifically in such a neighborhood.

A careful comparative study of the Niagaran deposits of New York and those of the middle states has brought out some important and interesting facts. These may be summed up in the

statement, that the New York fauna is more individualized, showing characteristics stamping it in some degree as a provincial fauna. The Niagaran fauna of the central states however is more closely allied to the European Mid-Siluric fauna than to that of New York state, from which we may conclude that the pathway of communication between the American and European Siluric seas was not by way of New York, a conclusion which is in entire harmony with those derived from the physical development of this region and the characteristics of the strata.

Weller[1] has collected data which indicate that the pathway of migration of faunas between the two continents was by way of the arctic region. According to Weller's interpretation of the facts, there existed in North America during Siluric time ". . . a north polar sea with a great tongue stretching southward through Hudson bay to about latitude 33°. There were doubtless islands standing above sealevel within this great epicontinental sea; and at the latitude of New York there was a bay reaching to the eastward, in which the Siluric sediments of the New York system were deposited. Labrador, Greenland and Scandinavia were in a measure joined into one great land area, though perhaps with its continuity broken, with a sea shelf lying to the north of it and another to the south. Another epicontinental tongue of this northern sea extended south into Europe, bending to the west around the southern part of the Scandinavian land and connecting with a Silurian Atlantic ocean. The sea shelf to the north of the Labrador-Scandinavian land was a means of intercommunication between northern Europe and the interior of North America, and the sea shelf to the south of this land was a pathway between England and eastern Canada." That portion of North America lying to the west of a line drawn from the Mississippi to the Mackenzie appears to have been dry land during the Niagara period, and connected with the Appalachian land on the east by the westward trending axis of the latter in the southern United States.

At the close of the Niagara period, there appears to have been an elevation of the continent which converted the Bay of New York

[1] Nat. hist. sur. Chicago acad. sci. bul. 4 and Jour. geol. 4:692-703.

and the greater part of the interior Siluric sea into a vast partially or entirely inclosed basin. This elevation appears to have been accompanied by climatic desiccation which brought about a rapid evaporation of the waters and a consequent increase in salinity. Thus this great interior water body was changed from a richly peopled mediterranean, to a lifeless body of intensely saline water, a veritable Dead sea. As the concentration of the brine continued, deposition of gypsum began, and later on the extensive beds of rock salt of this formation were laid down. Some of these salt beds in Michigan are reported to be a thousand feet thick, but none of the New York beds approach this thickness. The clastic strata of the Salina series were probably derived from the destruction of the sediments which were formed during the early periods of the Siluric and during preceding periods. This would account for the presence of limestone beds in deposits formed in a lifeless sea. All these limestones were more or less mixed with clayey sediments; they may in fact be regarded as consolidated argillo-calcareous muds derived from older limestones and shales. This is the character of the Waterlime and Manlius limestone which succeed the Salina beds, and which, though fossiliferous, could have no other source of origin than preexisting limestone beds.

The Waterlime has been regarded as a fresh-water formation. It is more likely however that it represents a return of marine conditions through the opening of channels between this interior basin and the ocean at large. This is indicated by the fauna, which includes undoubted marine forms. Whether this connection was through the old northern channel, or whether a new channel toward the east was opened is not apparent. The former is indicated by the character of the Manlius limestone which succeeds the Waterlime, and which in the Niagara region has features associating it with the corresponding deposits of Ohio, Michigan and Ontario, rather than its eastern equivalents. Whatever the nature of the transgression of the sea which took place in the late Siluric, it was not of long duration. The epoch of the Manlius limestone and with it the Siluric era were brought to a close with the withdrawal of all the waters from this portion of the continent, which thereafter for

a long period of time remained above the sea. During this time, the Helderbergian and other Lower Devonic strata were deposited in the Appalachian region, which by that time had established a southern connection with the open Atlantic.

Finally, toward the middle of the Devonic era, the sea once more transgressed on the abandoned continent, and again all this region was covered by oceanic waters. On the land surface of early Devonic times, now grew corals in great luxuriance; and reefs of great extent, with their accompanying deposits of coral sands, and their wealth of new life, again characterized the interior Paleozoic sea. It was not till long ages after, that this portion of the continent was again raised above the sea. This last elevation, which took place toward the close of Paleozoic time, was a permanent one, with the exception of a possible slight resubmergence of some parts of this region after the close of the glacial period. With the last great emergence of the land were inaugurated those long cycles of erosion outlined in chapter I, which resulted in the formation of the great topographic features of this region, and which came to a close only with the envelopment of this region in the snow and ice of the great glacial winter.

Chapter 4

FOSSILS OF THE NIAGARA REGION[1]

PLANTS

The Paleozoic marine plants or seaweeds are generally classed together as " fucoids ", a term denoting a relation of these organisms to the modern rockweed, Fucus, which fringes the rocks of our seacoast. These plants were probably algae, but it is impossible in most cases to make a more precise classification. The condition in which these remains are found today—as a rule mere impressions or casts of the original—generally renders the determination of their affinities a hopeless task. In some remains the plant nature of the organism is even questionable.

Genus BYTHOTREPHIS Hall

[Ety.: βυθοτρεφής, growing in the deep]

(1847. *Pal. N. Y.* 1:8)

Plant consisting of subcylindric or compressed stems, usually flattened on the rock surfaces and having numerous spreading branches, which in some species are leaf-like.

Bythotrephis gracilis Hall (Fig. 25) (1852. *Pal. N. Y* 2:18, pl. 5)

Distinguishing characters. Slender branches diverging at varying angles from a central stipe which not infrequently bifurcates. Terminations of branches round to pointed.

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[1] In this chapter only the Siluric fossils of the Niagara region will be considered, those of the Devonic limestones, which border this region on the south being so numerous that they must be reserved for a future publication. No attempt is made to add to the number of known species of Siluric fossils of the Niagara region. Of described species those only which have been found in this region or recorded in the literature as coming from it have been included, with the addition of such species from neighboring localities as occur there abundantly, and may reasonably be expected to occur in the Niagara sections. An exhaustive study of the Niagara fauna of western New York has still to be made. In chapter 5 a complete account of all the post-Pliocene shells so far found in the Niagara gravels is given, this being the first time that these shells are described and illustrated.

These organisms occur as mere impressions on the rock surfaces, varying in slenderness of branches from less than 1 mm to 5 mm (varieties intermedia and crassa).

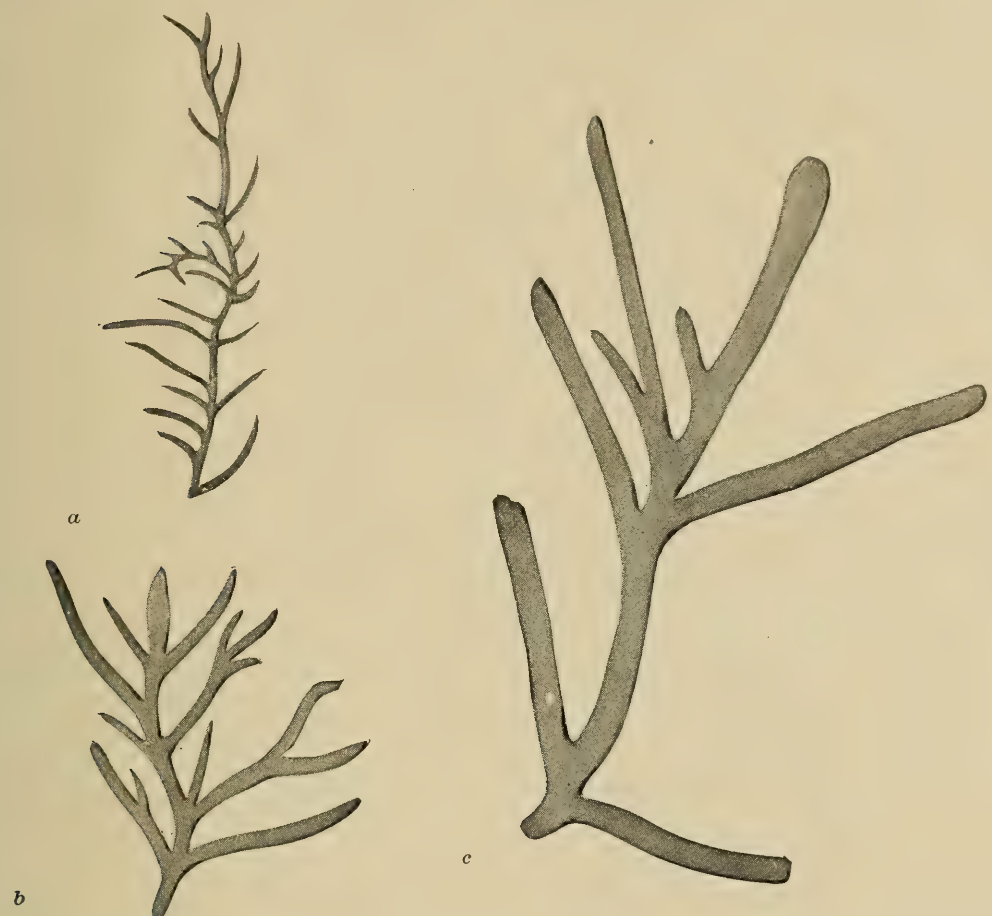


Fig. 25 Bythotrephis gracilis; showing varieties. *a* B. gracilis; *b* B. gracilis var. intermedia; *c* B. gracilis var. crassa

Found in the shaly partings separating the thin beds of the lower Clinton limestone at Niagara.

Bythotrephis lesquereuxi Grote & Pitt (Fig. 26) (1876. *Buffalo soc. nat. sci. Bul.* 3:88, 4:20, fig. 6)

Distinguishing characters. Flattened, erect stem; simple, sparingly dichotomous branches, 3-4 mm thick, gradually widening to nearly 1 cm at the very obtuse or round truncate point;

Fig. 26 Bythotrephis lesquereuxi

smooth surface; branches mostly simple from the base 13-14 cm long.

Found in the cement beds of the Waterlime, Buffalo (N. Y.) (Grote & Pitt)

Genus ARTHROPHYCUS Hall

[Ety.: *ἄρθρον*, a joint; *φῦκος*, a seaweed]

(1852. *Pal. N. Y.* 2:4)

Stems simple or dividing at the beginning and remaining simple thereafter; rounded or subangular, flexuous, transversely marked by ridges or articulations.

Arthrophycus harlani (Conrad) (Plate 16) (1852. *Pal. N. Y.* 2:5, pl. 1 and 2)

Distinguishing characters. Strong, rounded articulated stems, dividing near the base into numerous elongated branches; simple, flexible, articulated branches which diminish in size very gradually.

Found on the under side of certain sandstone beds in the upper part of the Medina in the Niagara section.

Genus NEMATOPHYCUS Carruthers

[Ety.: *νῆμα*, thread; *φῦκος*, seaweed]

(1872. *Month. micro. jour.*)

Considered a gigantic alga, with cylindric branching stems, and a peculiar structure which led Dawson to refer it to the Coniferae under the name P r o t o t a x i t e s. What resemble concentric rings of growth and medullary rays appear; cells irregular, cylindric, thick walled. The specimens are generally silicified.

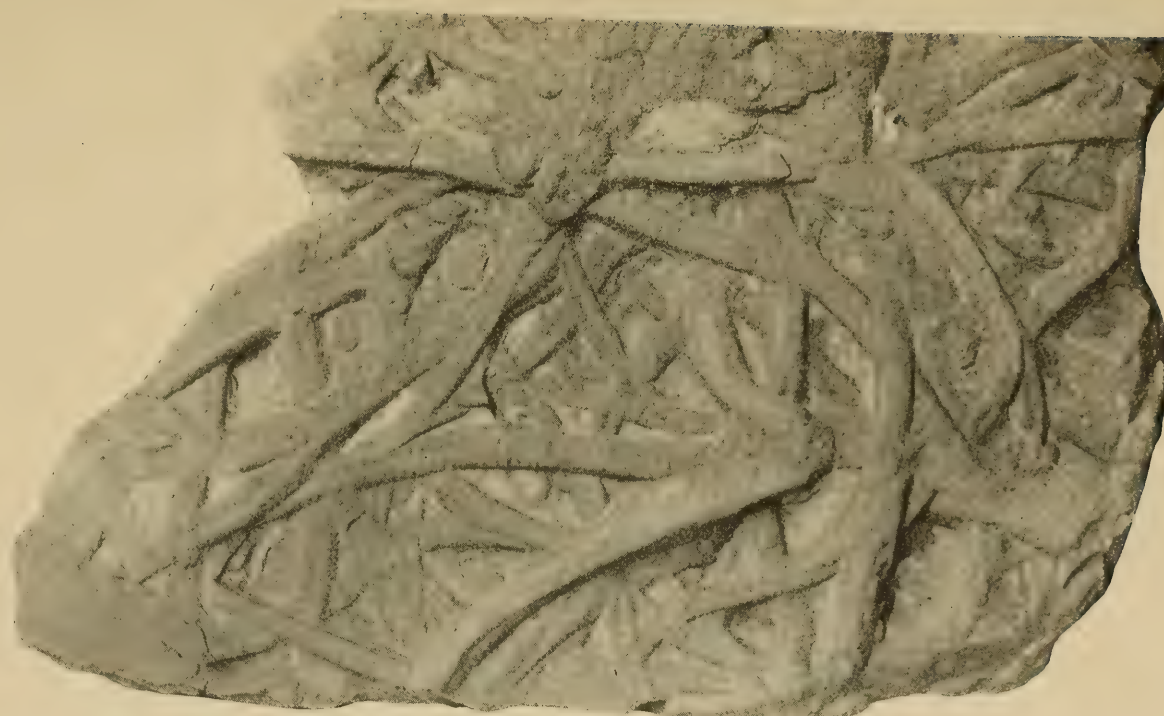
Nematophycus crassus (Penhallow) (1896. N e m a t o p h y t o n c r a s s u m Penhallow. *Can. record of science.* July 1896, 7:151-56, pl. 2)

Distinguishing characters. Section showing numerous irregular round or oval medullary spots; large cells in groups, thick walled.

The specimen is the basal portion of a stock showing root processes; length 56 cm, diameter at upper end 7.5 cm, widening toward base to 16.5 cm.

Found in the Manlius limestone of North Buffalo. (F. K. Mixer)

Plate 16



Arthrophycus harlani Conrad; upper Medina sandstone. Slightly reduced (original)

ANIMALS

Class HYDROZOA Owen

This class includes the simplest polyps, of which the fresh-water Hydra is an example. The body consists of a hollow tube, the walls of which are composed of two cellular layers, *ectoderm* and *endoderm*, with a non-cellular layer, the *mesogloea*, between them. These layers meet at the mouth, which is the only opening into the gastric space inclosed by the body wall. Tentacles, furnished with nettle cells, surround the mouth.

A few hydroids are simple forms, but the majority are united into colonies, which frequently assume a branching or tree-like character, a polyp occupying the end of each branch. Reproduction is usually carried on by specially modified polyps, the *gonopolyps*, which produce jellyfish or medusae. These may remain attached to the colony or become free-swimming.

Some hydroids are entirely unprotected, no hard structures being developed, and these consequently leave no remains. The majority of species, however, secrete a horny or chitinous covering, the *periderm*, which invests the whole stock, and in one group is expanded at the ends of the branches into cups or *hydrothecae*, into which the polyps can withdraw. This chitinous periderm may be preserved in the form of a carbonaceous film (e. g. Dictyonema and Graptolites).

Some hydroid colonies, i. e. the hydrocorallines, secrete at the base a dense calcareous covering, which has much the aspect of coral, and is frequently mistaken for that (e. g. Millepora, Stromatopora). Most hydroid colonies are permanently attached to rocks, seaweeds, or other objects of support.

Genus DICTYONEMA Hall

[Ety.: δίκτυον, net; νῆμα, thread]

(1852. *Pal. N. Y.* 2:174)

Colony forming a network of anastomosing branches, the whole commonly flattened on the rock surface, but originally forming a funnel or fan-shaped expansion. The branches proceed from a common acute base, divide frequently, and are at intervals united again by transverse dissepiments. The outer surfaces of the branches are striated; the inner bear hydrothecae, though these are seldom seen in the flattened specimens.

Dictyonema retiforme Hall. (Fig. 27) (1852. *Pal. N. Y.* 2:174, pl. 40F)

Distinguishing characters. Form circular or cup-shaped in growing state; thin, flat, frequently bifurcating branches, united laterally by obliquely transverse filaments, leaving oblong quadrangular interstices; indented or obliquely and intermittently striated surfaces.

Fig. 27 Dictyonema retiforme

Found rarely in the lower part of the Rochester shales in the Niagara section; usually fragmentary. Abundant at Lockport and elsewhere. (Hall)

Genus STROMATOPORA Goldfuss

[Ety.: στρῶμα, a covering; πόρος, a pore]

(1826. *Petrefacta Germaniae*, p. 22)

Skeleton forming hemispheric, globular or expanded masses composed of numerous concentric, undulating calcareous laminae, separated by interspaces, and connected by radial pillars which unite with the thick concentric laminae and form a finely reticulate tissue, visible in cross-section. Traversing the entire mass are sparsely scattered tubes which are divided by numerous tabulae or horizontal floors, and were occupied by the larger polyps of the colony. Base of entire skeleton covered by a wrinkled "epitheca".

Stromatopora concentrica Goldfuss Hall (Fig. 28) (1852, *Pal. N. Y.* 2:136, pl. 37)

Distinguishing characters. Hemispheric or spheroidal form sometimes irregular; thin concentric laminae, readily visible in weathered specimens, and scarcely of the thickness of writing paper; surface of laminae marked by fine pores.

This coralline is generally very massive and may attain a diameter of 2 feet. Probably includes a number of distinct species.

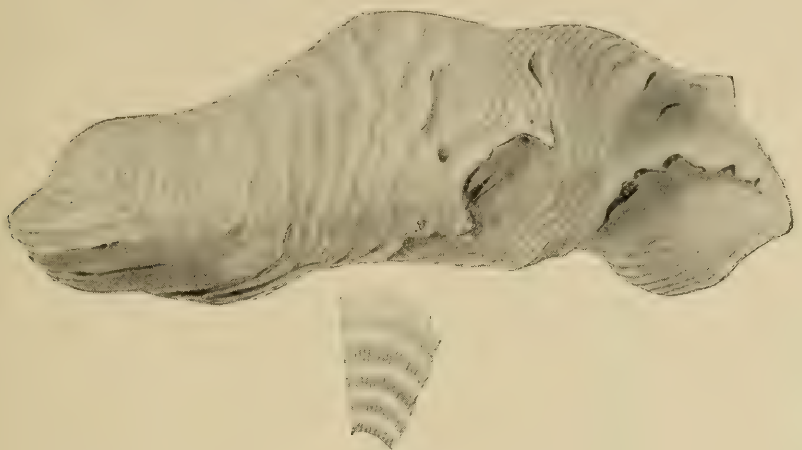


Fig. 28 Stromatopora concentrica Hall with an enlargement of a cross-section

Found at Niagara in the Lockport limestone, particularly the geodiferous beds, and generally common throughout the middle limestones. Also at Lockport and elsewhere.

Class ANTHOZOA Ehrenberg

The Anthozoa, or coral polyps, are marine animals ranging from low water to 300 and sometimes even 1500 fathoms (Zittel). The reef-building types however do not flourish in depths greater than 50 fathoms, and are generally restricted to 20 fathoms or less. Both simple and colonial forms occur, the latter predominating at the present time, while the former were abundant in the Paleozoic. The two important types of Paleozoic corals are the "rugose corals" or Tetracoralla, and the tabulate corals, the former generally simple, the latter colonial types.[1]

The simple rugose corallum is well represented by Enterolasma. It consists of numerous radiating *septa*, disposed in several cycles, and united round their outer margins by a wall or *theca* (*pseudotheca*). This is formed by the lateral expansion or thickening of the septa in that region. The exothecal prolongations of the septa are visible on the exterior of the corrallum as costae, which are frequently represented by grooves instead of ridges. These, in the genus referred to, as well as in others, commonly show the peculiar tetrameral arrangement characteristic of the septa of this group. On or near the convex longitudinal surface of the corallum a median, or " cardinal ", septum appears, from which the

[1]As no true Hexacoralla occur in the formations treated of in these pages, an account of their structure is omitted.

secondary septa pass off in a pinnate manner (fig. 29). 90° toward either side occur the "alar" septa. These are parallel[1] to the secondary septa which branch off from the cardinal septum. They have a single series of secondary septa branching off from them on the side away from the *cardinal quadrants*. The two remaining, or *counter quadrants*, are filled with parallel septa, which branch off, in a pinnate manner, from the alar septa, and are completed in front by the *counter septum* to which they are all parallel.

One of the four "primary septa"—commonly the cardinal septum—may be aborted, leaving a groove or *fossula*. Between the septa various endothecal tissues may be developed, such as cross plates, or *dissepiments* connecting adjoining septa; *tabulae*, or floors more or less completely dividing the whole inner space, irrespective of the septa; and *cysts*, which form a vesicular tissue more or less regularly disposed (Cystiphyllum). The cup or calyx may be limited below by a continuous floor, by dissepiments or otherwise, or it may be limited only by the margins of the septa, the spaces between the septa being open to the bottom of the corallum. The costae are commonly covered by a concentrically wrinkled *epitheca*, which forms the outermost wall of the corallum.

In colonial forms the adjacent corallites commonly become prismatic from crowding. The separate thecae may be retained, or they may become obsolete, the corallites becoming confluent. The epithecal covering in these forms is commonly confined to the free margins of the outer corallites, and surrounds the whole colony as a *peritheca*.

The tabulate corals are invariably compound, either loosely or compactly, and consist of tubular or prismatic corallites commonly with thick walls, which in certain groups are perforated by *mural pores*. Septa are absent or but slightly developed, sometimes being represented merely by vertical ridges or rows of spines. The number is usually six or 12. The corallites are crossed by numerous *tabulae* which cut off the empty portion of the tube below the polypite. Other endothecal structures are absent.

The reproduction of the Anthozoa is both sexual and asexual, the latter by lateral or calycinal budding, or by fission.

Genus ENTEROLASMA Simpson

[Ety.: ἔντερον, intestine; ἔλασμα, lamella]

(1900. *N. Y. state mus. Bul.* 39, p. 203)

Corallum simple, turbinate and usually straight. Septa numerous, those of the earlier cycles reaching nearly to the center, where they have projections which reach to the center, becoming much involved and forming a pseudocolumella of very peculiar appear-

[1] Parallel as seen in the costae.

ance, somewhat resembling the convolutions of the intestine; those of the last cycles short; all with papillate elevations or carinae on the sides, giving in section a crenulate or echinate appearance. Dissepiments present. Epitheca well developed.

Enterolasma caliculus (Hall) (Fig. 29) Streptelasma caliculus Hall (1852. *Pal. N. Y.* 2:111, pl. 32)

Distinguishing characters. Turbinate, oblique or curved, more or less rapidly expanding form; moderately deep cup; septa 20 to 50, separated by a space of twice their width; well marked costal grooves which lie opposite both long and short septa; relatively thin and smooth epitheca.

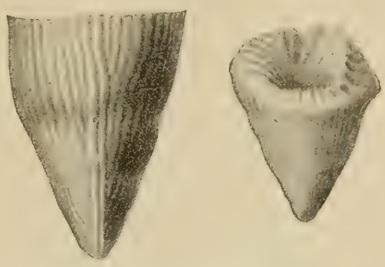


Fig. 29 Enterolasma caliculus

Found rarely in the upper Clinton beds, and abundantly in the lenses of limestone in the Clinton, the lower part of the Rochester shales and the Bryozoan beds of these shales. Also in the same shales at Lockport and farther east.

Genus ZAPHRENTIS Rafinesque

[Ety.: ζα, many; φρήν, diaphragm]

(1820. *Ann. des sci. phys.* Brux. 5:234)

Corallum simple, conic or turbinate, or conico-cylindric, with a deep calyx, and well developed septa, the primary ones reaching to the center. Dissepiments and tabulae occur, the latter usually well developed. A deep fossula marks the abortion of one of the four primary septa. Costae and a thin epitheca occur.

Zaphrentis turbinata (Hall) (Fig. 30). Polydilasma turbinatum Hall (1852. *Pal. N. Y.* 2:112, pl. 32)

Distinguishing characters. Form variable, usually short and turbinate; calyx gradually deepening from margin halfway to the center and then abruptly descending, almost vertically to a moderate depth; alternate septa terminating at point of sudden deepening of calyx, others reaching to center; dissepiments slightly developed.

Found in the Lockport limestone at Niagara(?) and Lockport, where it occurs a few feet above the shale.

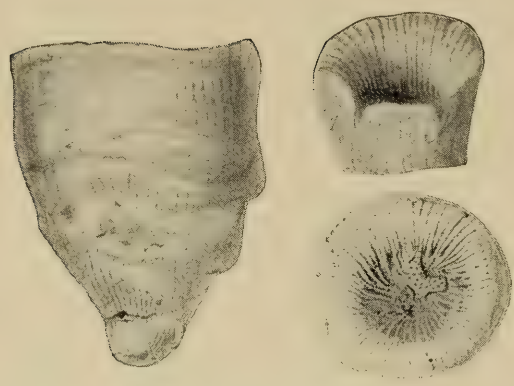


Fig. 30 Zaphrentis turbinata

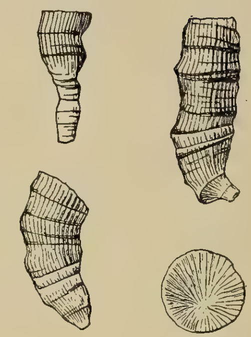


Fig. 31 Cyathophyllum hydraulicum

Genus CYATHOPHYLLUM Goldfuss

[Ety.: κύαθος, a cup; φύλλον, a leaf (septum)]

(1826. *Petrefacta Germaniae*, p. 54)

Corallum normally simple, the individuals conic, or conico-cylindric. Septa well developed, radially arranged, the larger extending to the center, where they are twisted into a pseudocolumella. Costae usually obsolete. Tabulae present but only in the center of the visceral chamber, the outer area being filled with vesicular dissepiments. Exterior covered with an epitheca.

Cyathophyllum hydraulicum Simpson. (Fig. 31) Grabau. Geol. soc. Am. Bul. 11:364, pl. 21, fig. la-d.

Distinguishing characters. Simple, conico-cylindric, slender, sometimes curved; growth irregular with abrupt changes in direction; strongly costate adult portion; non-costate young; well developed epitheca, which often shows coarse wrinkles; calyx somewhat less deep than its diameter; numerous strong thin and rather widely separated septa, meeting in center where they are slightly twisted, and not infrequently uniting before they reach the center; well developed dissepimental structures.

Found abundantly in the upper Manlius limestone of the Niagara region, but only as external molds in the limestone. Gutta percha casts however show the characters well.

Genus CHONOPHYLLUM Edwards & Haime

[Ety.: χόνος, a funnel; φύλλον, a leaf (septum)]

(1850. *British fossil corals*, p. 69)

Corallum simple, chiefly consisting of a series of funnel-shaped tabulae, set one into the other. On the surfaces of these, equally developed septal radii extend from center to circumference; no walls or columella.

Chonophyllum niagarense Hall (Fig. 32)
(1852. *Pal. N. Y.* 2:114, pl. 32)

Distinguishing characters. Irregularly cylindric, elongated or subturbinate form, more or less expanding above; deep and regularly concave calyx; thin denticulate septal ridges, which are separated by a space equal to their width; rough external surface of weathered specimens.

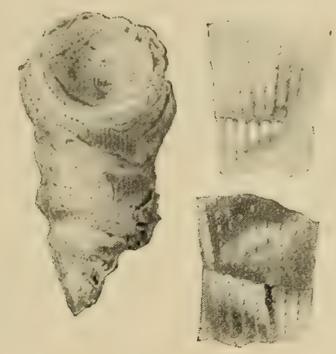


Fig. 32 Chonophyllum niagarense with enlargement of interior of calyx

Hitherto found only in the lower part of the Lockport limestone at Lockport, but probably also occuring at Niagara.

Genus DIPLOPHYLLUM Hall

[Ety.: διπλόος, double; φύλλον, septum]

(1852. *Pal. N. Y.* 2:115)

Corallum simple and branching, or forming compound masses of loosely aggregated corallites which are cylindric, consisting of two distinct parts separated by an accessory wall, the inner transversely septate, the outer with fine transverse dissepiments uniting the septa which are continuous to the center. Calyxes deeply concave in the center, and separated from the outer portion by a distinct rim.

Diplophyllum caespitosum Hall (Fig. 33) (1852. *Pal. N. Y.* 2:116, pl. 33)

Distinguishing characters. Subturbinate young, and cylindric adult corallites, which coalesce at intervals and increase by lateral budding; cespitose or aggregated into large masses which often grow from a single base; strongly costate exterior; numerous thin septa, all of which reach the center.

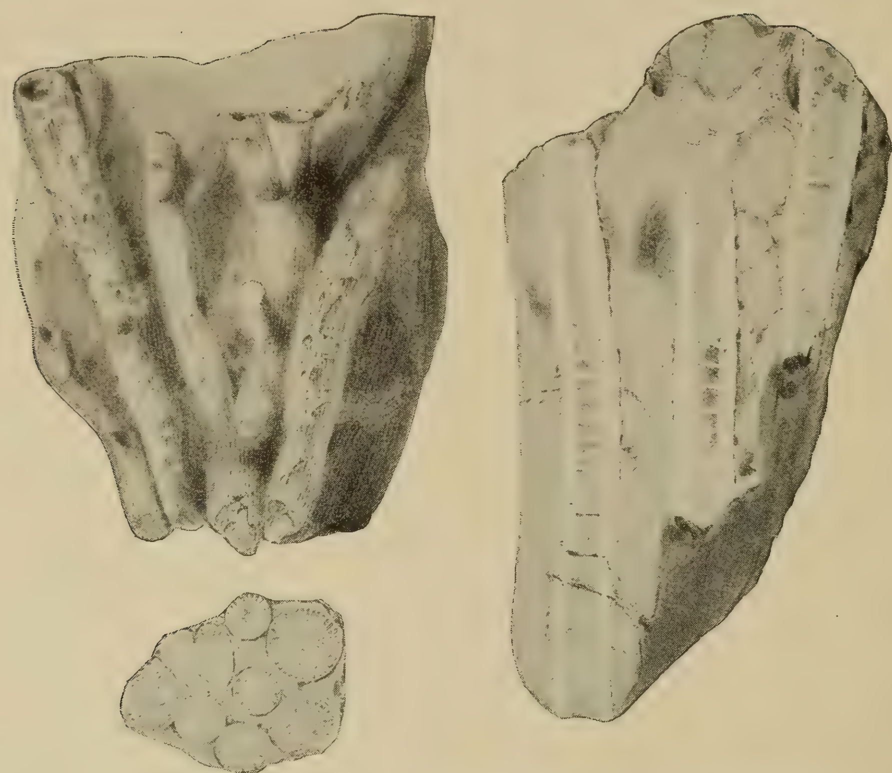


Fig. 33 Diplophyllum caespitosum with longitudinal and transverse sections

Found in the lower part of the Lockport limestone series at Lockport, and may also occur at Niagara.

Genus FAVOSITES Lamarck

[Ety.: *favus*, honeycomb]

(1816. *Hist. des anim. sans vert.* 2:204)

Corallum massive, more rarely branching, commonly forming heads which may be a foot or more in diameter. Corallites prismatic, thin, in contact but not amalgamated by their walls, which are perforated by equidistant mural pores in one or more rows. Septa rudimentary or obsolete. Numerous more or less regular tabulae divide the intrathecal space. Peritheca present on the under side of the colony, and usually strongly wrinkled.

Favosites venustus (Hall)[1] (Fig. 34). Astrocerium venustum Hall (1852. *Pal. N. Y.* 2:120, pl. 34)

Distinguishing characters. Hemispheric or spheroidal form, beginning growth on other bodies; small corallites increasing in number by interstitial addition; 12 ascending septal spines between tabulae; corallites from .9 to 1 mm in diameter; heads often up to 2 or 3 feet in diameter.

[1]These species are regarded by Whiteaves and Lambe as synonyms of Favosites hisingeri E. and H.

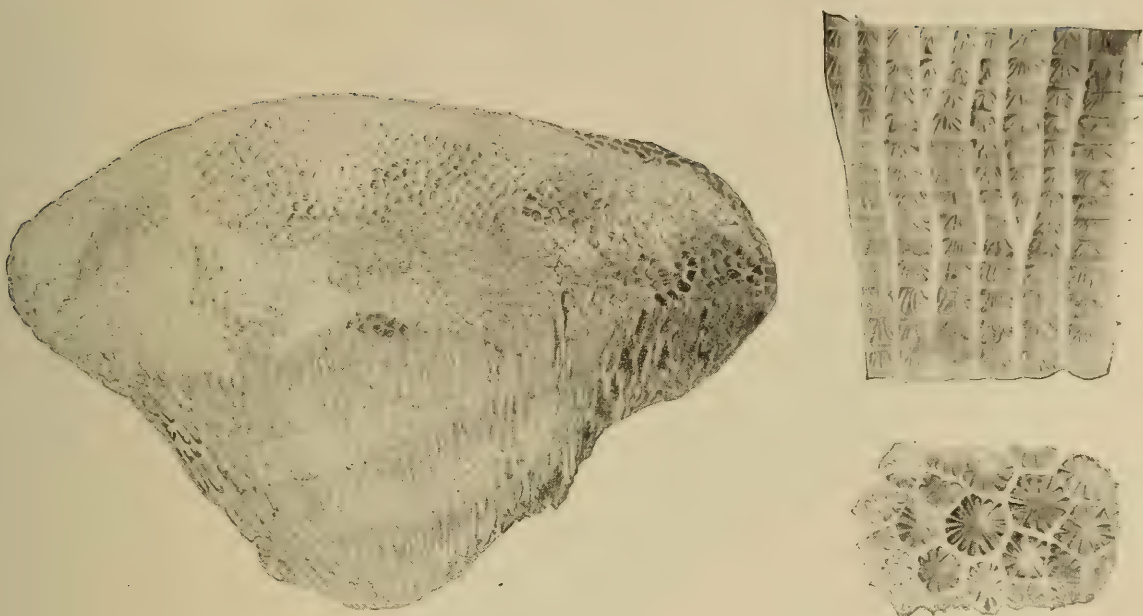


Fig. 34 Favosites venustus with longitudinal and transverse sections

Found in the Lockport limestone at Lockport and Niagara, often replaced by anhydrite or other materials.

Favosites parasiticus (Hall)[1] (Fig. 35). Astrocerium parasiticum Hall (1852. *Pal. N. Y.* 2:122, pl. 34) Not F. parasiticus Phillips.

Distinguishing characters. Hemispheric or spheroidal coralla, independent or attached to, or enveloping other bodies; unequal size of calyxes, which are stellate from septal spines, of which there are from 12 to 24; subcircular outline of some of the larger calyxes, the majority being angular.

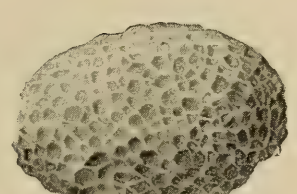


Fig. 35 Favosites parasiticus

Found in the Bryozoan bed of the Rochester shales in the Niagara sections. Also in the lower part of the limestone at Lockport (Hall).

Favosites pyriformis (Hall)[1] (Fig. 36). Astrocerium pyriforme Hall (1852. *Pal. N. Y.* 2:123, pl. 34A)

Distinguishing characters. Irregularly subturbinate, pyriform or spheroidal form of corallum; corallites radiating from a more or less extended base, spreading out above and rapidly increasing in number by interstitial addition; calyxes varying from triangular to

[1]These species are regarded by Whiteaves and Lambe as synonyms of Favosites hisingeri E. and H.

hexagonal, not rounded and varying in size according to age of individual; septal spines in one or more rows.

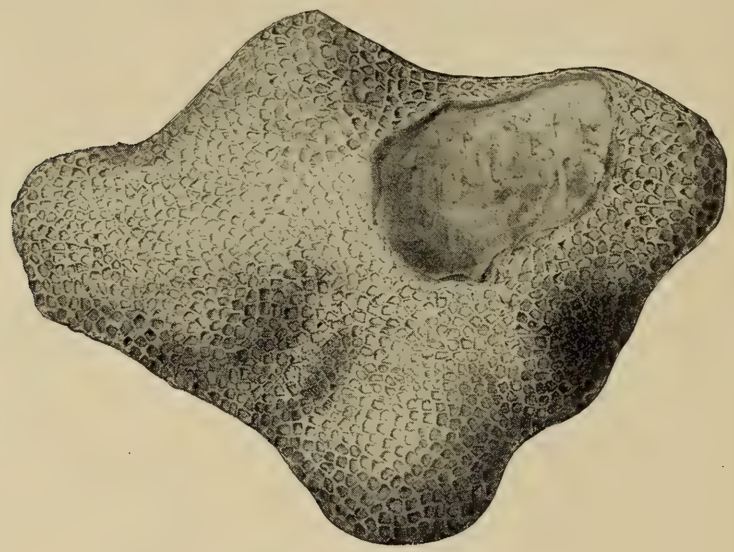


Fig. 36 Favosites pyriformis

Found in the Rochester shale and Lockport limestone at Lockport (Hall). Probably occurs also at Niagara.

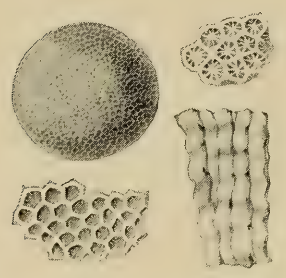


Fig. 37 Favosites constrictus; a group of corallites enlarged, and enlargements of the calyxes

Favosites constrictus (Hall) (Fig. 37). Astrocerium constrictum Hall (1852. *Pal. N. Y.* 2:123, pl. 34A)

Distinguishing characters. Small size; hemispheric form; minute corallites which appear constricted at intervals; calyxes appear stellate.

Found in the Rochester shale at Lockport and other places (Hall). Probably also at Niagara.

Favosites niagarensis Hall (Fig. 38) (1852. *Pal. N. Y.* 2:125, pl. 34A)

Distinguishing characters. Spheroidal to irregular form, rapidly increasing in size by interstitial addition of corallites; thin walled corallites with mural pores in double rows; tabulae often oblique or bent downward; calyxes varying in size with varying age of individual; septal spines obsolete.

Found in the Lockport limestone at Niagara and Lockport.

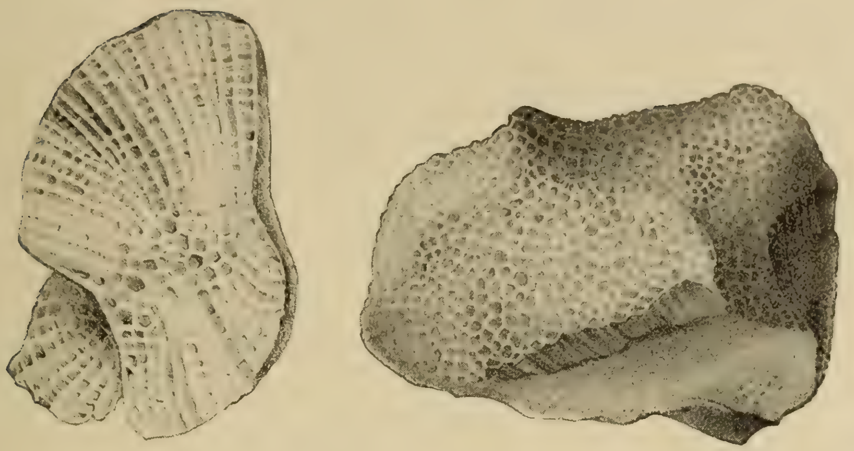


Fig. 38 Favosites niagarensis

Genus HALYSITES Fischer

[Ety.: ἅλυσις, a chain]

(1813. *Zoognosia.* 3d ed. t. 1, p. 387)

Corallum forming a clustered and reticulated mass, composed of long tubular, cylindric or compressed corallites, which are placed side by side in intersecting and anastomosing laminae or lines, any given corallite being united along its whole length with its neighbors to the right and left, and each lamina of the corallum consisting of no more than a single linear series of tubes. Walls of the corallites strong and without pores, the free portions covered by a continuous thick epitheca showing lines of growth. Small corallites often alternate with the larger ones. Septa obsolete or represented by vertical rows of spines in cycles of 12. Tabulae well developed, complete and simple, more numerous in the smaller corallites.

Halysites catenulatus (Linn.) (Fig. 39). Catenipora escharoides (Lamarck) Hall (1852. *Pal. N. Y.* 2:127, pl. 35)

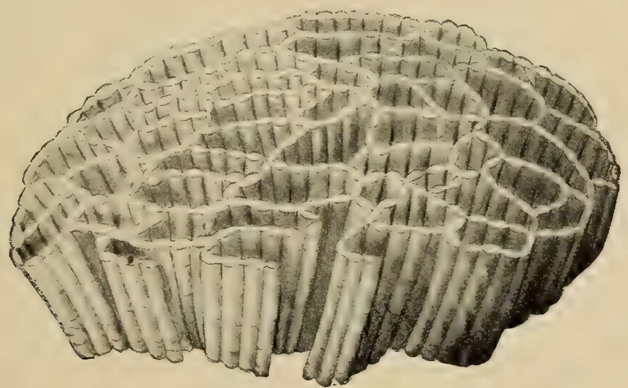


Fig. 39 Halysites catenulatus

Distinguishing characters. Corallites in juxtaposition or separated by cellular interspaces; large meshes of the network irregular, greatly varying in size; corallites oval in cross-section, united by their narrower sides; epitheca with fine lines of growth and occasionally strong wrinkles.

Found in the Lockport limestone at Lockport (Hall), and Niagara. When silicified, the coral may be well preserved, but otherwise it is usually almost destroyed or replaced by various minerals.

Genus HELIOLITES Guettard

[Ety.: ἥλιος, the sun; λίθος, a stone]

(1770. *Mem.* 3:454)

Corallum spheroidal, pyriform, hemispheric, or rarely ramose. Corallites (macrocorallites) cylindric, comparatively few in number

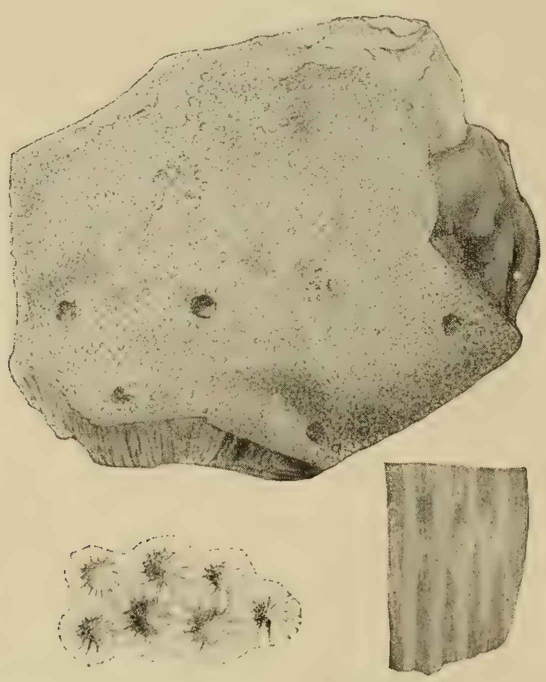


Fig. 40 Heliolites elegans with enlargement of calyxes and longitudinal section

and furnished with 12 lamellar infoldings of the wall, or pseudosepta. Smaller corallites (microcorallites) completely investing the larger ones, more or less regularly polygonal in form, with distinct walls, completely amalgamated with one another and with the walls of the larger corallites. Mural pores absent. Both kinds of corallites with tabulae, most numerous in the smaller corallites. Base of corallum covered by a peritheca showing lines of growth.

Heliolites elegans Hall (Fig. 40) (1852. *Pal. N. Y.* 2:130, pl. 36)

Distinguishing characters. Hemispheric form of corallum, which increases in size by lateral rather than interstitial addition; from 16 to 18 larger calyxes to the inch; pseudosepta reaching halfway to the center; microcorallites generally appearing solid; macrocorallites often standing out in relief in weathered specimens and having a stellate appearance.

Found in the lower part of the Lockport limestone at Lockport (Hall). May occur also at Niagara.

Heliolites spiniporus Hall (Fig. 41) (1852. *Pal. N. Y.* 2:131, pl. 34)

Distinguishing characters. Turbinate, pyriform, hemispheric or spheroidal form of corallum; divergent corallites, increasing in

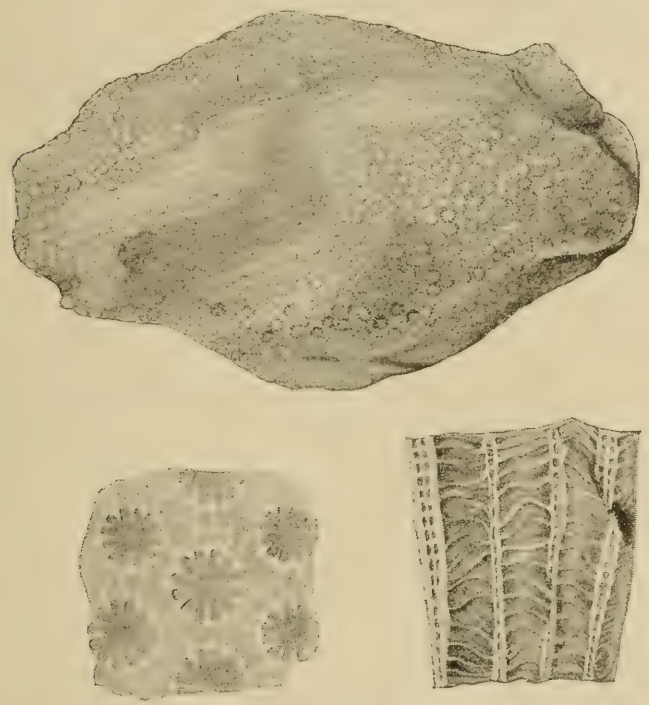


Fig. 41 Heliolites spiniporus with longitudinal and transverse sections enlarged

number by interstitial addition; circular macrocorallites with 12 pseudosepta, which extend only part way to the center; irregular or interrupted tabulae which often appear spiniform in section; microcorallites in one or more series, angular and tabulate.

Found in the lower part of the Lockport limestone at Lockport (Hall). Probably also at Niagara.

Heliolites pyriformis Guettard (Fig. 42) (Hall. 1852. *Pal. N. Y.* 2:133, pl. 36A)

Distinguishing characters. Macrocorallites larger than preceding, and generally more widely separated; mostly several series of micro-

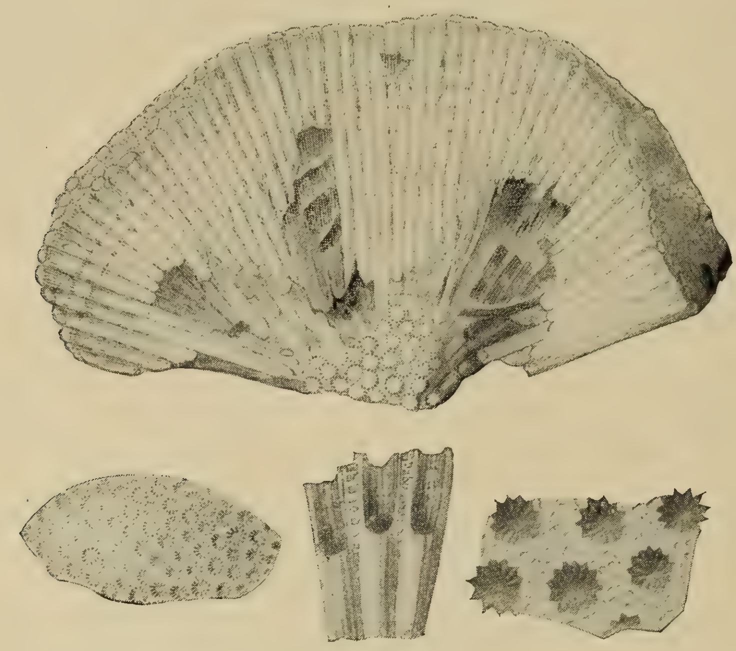


Fig. 42 Heliolites pyriformis

corallites, though they may sometimes be absent when macrocorallites are in contact; short pseudosepta.

Found commonly in the lower Lockport limestone at Lockport (Hall). Probably also at Niagara.

Genus CLADOPORA Hall

[Ety.: κλάδος, twig; πόρος, pore]

(1852. *Pal. N. Y.* 2:137)

Corallum branching or reticulate; branches cylindric or slightly compressed with terete terminations. Corallites small, radiating equally on all sides from the axis, and opening on the surface in rounded or subangular expanded calyxes, which are generally contiguous, and apparently destitute of septa.

Cladopora seriata Hall (Fig. 43) (1852. *Pal. N. Y.* 2:137, pl. 38)

Distinguishing characters. Nearly parallel, rather closely crowded branches, forming a glomerate mass, the branches sometimes

bifurcating; closely arranged corallites, gradually enlarging toward the surface of the branches. Calyxes in alternating series each margined on the lower side by a projecting circular lip.

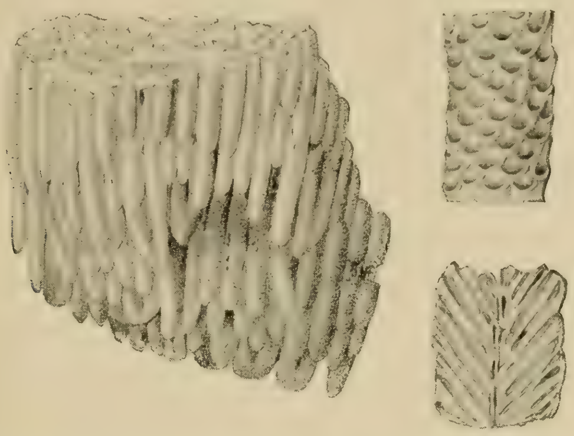


Fig. 43 Cladopora seriata with enlargement of a single branch showing the calyxes, and a section of same showing position of corallites

Found in the lower part of the Lockport limestone at Lockport (Hall), and in the Bryozoan bed of the Rochester shale at Niagara.

Cladopora multipora Hall (Fig. 44) (1852. *Pal. N. Y.* 2:140, pl. 39)

Fig. 44 Cladopora multipora, with enlargements

Distinguishing characters. Ramose or irregularly reticulate form, with the branches often extending beyond the last point of junction and ending in terete extremities; numerous closely arranged corallites, which are slightly oblique to the axis; calyxes subangular or circular, from 48 to 60 in the space of an inch.

Found in the lower part of the Lockport limestone at Lockport (Hall). Probably occurs also at Niagara.

Genus STRIATOPORA Hall

[Ety.: *striatus*, striated; *porus*, pore]

(1852. *Pal. N. Y.* 2:156)

Corallum dendroid, forming simple dividing, cylindric stems. Corallites essentially polygonal, diverging from an imaginary central axis, their walls greatly thickened by a secondary deposit of cal-

careous material or sclerenchyma, which increases in amount toward the calyxes. Calyxes in the form of circular apertures surrounded by a cup-shaped, thickened margin, the floor of which is striated by rudimentary septal ridges. Septal spines in vertical rows occasionally present. Tabulae few, widely separated, but extending completely across. Mural pores comparatively numerous, circular, and irregularly distributed.

Striatopora flexuosa Hall (Fig. 45) (1852. *Pal. N. Y.* 2:156, pl. 40B)

Distinguishing characters. Bifurcating or irregularly ramose stems with teretely terminating branches; calyxes circular, surrounded by large depressed cells, polygonal in outline and bounded by angular ridges; calycinal orifice in lower part of polygonal cell, vertically striate, the stria continuing upward in the surrounding cell.

Fig. 45 Striatopora flexuosa with an enlargement of several calyxes

Found not uncommonly in the Bryozoan bed of the Rochester shale at Niagara, generally well weathered out. Also in the same shale at Lockport (Hall).

Class CYSTOIDEA von Buch

The cystoids are entirely extinct marine invertebrates which flourished only during Paleozoic time. Most of them lived during the Ordovicic or Siluric eras, but Cambric and Carbonic forms are also known. They were mostly stemmed organisms with a *calyx* and imperfect *arms* like the crinoids, but a few of them were stemless. The *calyx*, which varies in form, is composed of polygonal plates which are united by close *sutures*. The plates vary in number in different species, from 13 to several hundred, and only exceptionally exhibit a regular arrangement. A radial arrangement of plates, like that of the Crinoidea occurs rarely, and the

side plates pass insensibly into the plates of the ventral (upper) side. In the center of the dorsal side, however, a regular series of *basal plates* exists, which rest on the stem or column.

The mouth is indicated by a central or subcentral aperture on the upper (ventral) surface, and is sometimes covered by small plates. From it radiate from two to five simple or branching ambulacral grooves, which are also frequently roofed over by plates. The *anal opening* is situated eccentrically and frequently closed by a valvular pyramid.

The calyx plates in most cystoids are perforated by pores or fissures. These are often arranged to form lozenge-shaped or rhombic figures, the *pore rhombs*, which are disposed one half on each of two adjoining plates, while the line of suture between the plates forms either the longer or the shorter diagonal of the rhomb. The pores of opposite sides of the rhomb are united by perfectly closed, straight ducts, which pass horizontally across the line of suture, and produce a transversely striated appearance (Caryocrinus, fig. 46). These striate rhombs are generally visible only in weathered specimens. They may be present on all plates or only on a few. In Callocystites and other related genera, the *pore rhombs* are reduced to *pectinated rhombs*, which are few in number, and each separated into two distinct parts, lying on contiguous plates (fig. 47). These structures have probably a respiratory function.

The *arms* are feebly developed in the cystoids and often but few in number. They are simple, consisting of a single (uniserial) or a double (biserial) row of plates, and possess a ventral groove, protected by covering plates.

Genus CARYOCRINUS Say

[Ety.: κάρυον, a nut; κρίνον, lily]

(1825. *Acad. nat. sci. Phil. Jour.* 4:289)

Calyx composed of a moderate number of plates arranged in a hexamerous manner, and with the base composed of two cycles of plates (dicyclic). Lowest (*infrabasals*) four, unequal; followed by a second row of six basals, which alternate in position with those of the preceding and succeeding cycles. Third cycle of eight plates of which six are regarded as *radials*, the others as *interradials* (Carpenter). Ventral surface formed of six or more small pieces. All plates of the calyx furnished with pore-rhombs; the summit plates without perforations. Mouth and ambulacral grooves below the ventral plates or *tegmen*. Anal opening protected by a valvular pyramid, and situated on the outer margin of the ventral surface. Arms, 6 to 13 in number, situated on the ventral margin, and relatively feeble. Stem long, composed of cylindric segments.

Caryocrinus ornatus Say (Fig. 46) (Hall. 1852. *Pal. N. Y.* 2:216, pl. 49 and 49A)

Distinguishing characters. Stem of larger and smaller joints alternating near the calyx; edges of joints thin and sharp, sometimes slightly crenulated or denticulated; articulating surface radiately striate halfway to the center; canal round; calyx ovoid to subglobose, the greatest diameter usually below the middle; summit

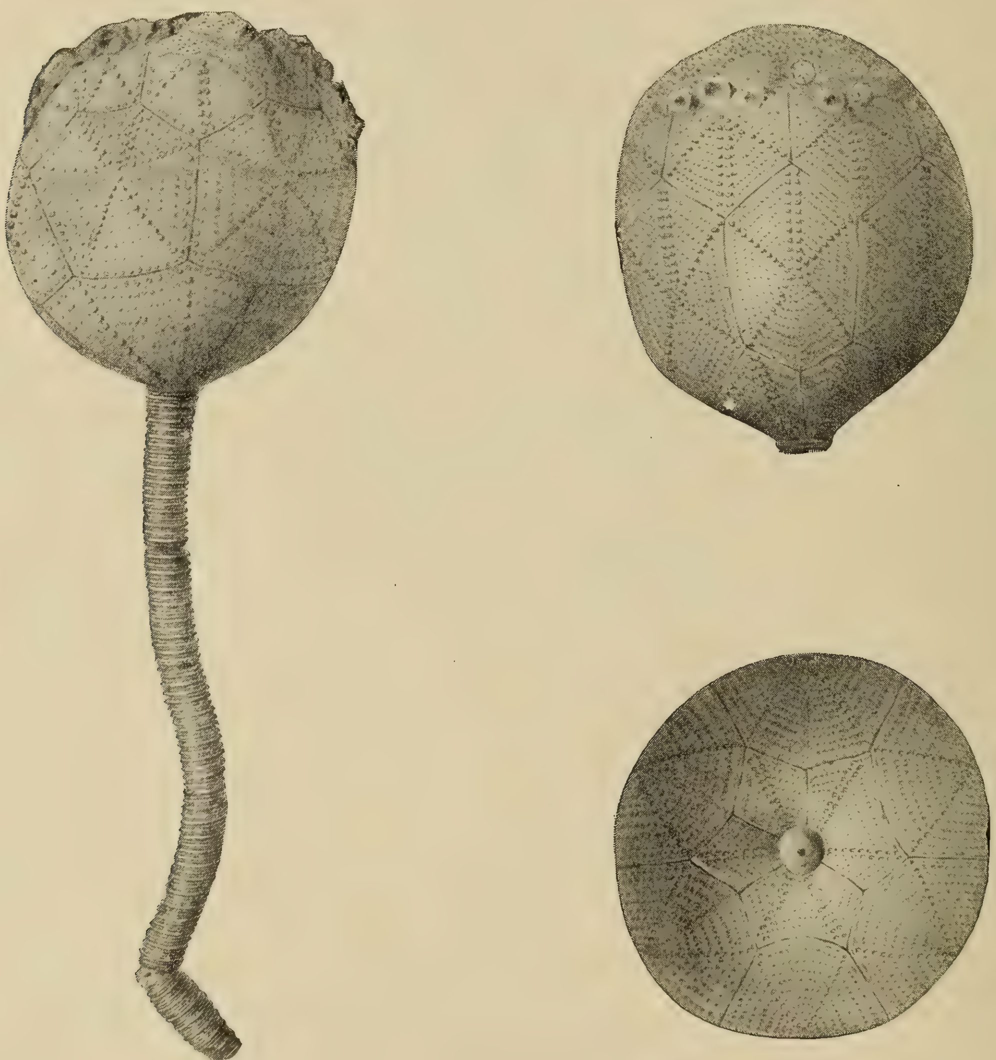


Fig. 46 Caryocrinus ornatus

slightly convex with arms sometimes several inches long; upper margins of radial and interradial plates indented for the arm plates. Mural pores represented on the exterior of the plates by single or double rows of tubercles radiating from the centers of the plates to their angles; between these are numerous rows of smaller tubercles parallel to the sides of the plates.

Found in the Rochester shale at Niagara, Lockport and other places. Often very abundant. At Niagara it has been found as low as 4 feet above the Clinton limestone, and from that upward as far as the Bryozoa beds, in which it occurs in moderate abundance. It has not been found above these beds. It occurs chiefly in the calcareous layers of the shale, from which it weathers out, the nut-like calyxes rolling to the bottom of the section where they can be picked up by the side of the railroad track.[1]

Genus CALLOCYSTITES Hall

[Ety.: κάλλος, beauty; κύστις, bladder]

(1852. *Pal. N. Y.* 2:238)

Calyx composed of large plates arranged in three or four cycles and having four pectinated rhombs, the component halves of which stand on contiguous plates and are separated by an interval. Mouth slit-like, and forming the center of radiation for two to five pinnulated arms, which sometimes bifurcate, and are protected by covering pieces, and either repose on the calyx or are sunk below the surface in grooves. Stem well developed tapering down to a point.

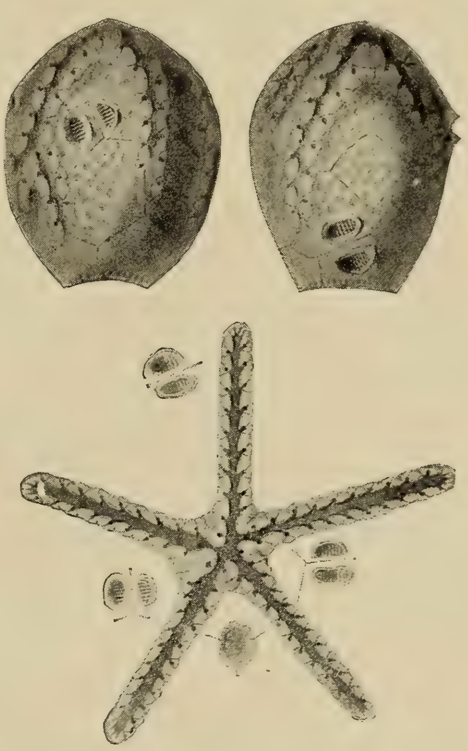


Fig. 47 Callocystites jewetti with the armgrooves spread out

Callocystites jewetti Hall (Fig. 47) (1852. *Pal. N. Y.* 2:239, pl. 50)

Distinguishing characters. Oblong ovoid, nearly symmetric form; base of four plates, one bearing part of pectinated rhomb; eight plates in second cycle; anal aperture between second and third cycle, excavated in two plates of the former and one of the latter; surface of plates ornamented by polygonal depressions, having a more or less defined border and granulose surface.

[1] Specimens of this "crinoid" may be purchased from John Garlow, the watchman on the middle section of the New York Central railroad cut in the gorge, at a moderate price.

Found in the Rochester shale at Lockport (Hall). Isolated fragments of plates have been obtained from the weathered lower Rochester shale in the Niagara gorge.

Class CRINOIDEA Miller

The crinoids, or sea lilies, are marine invertebrates, represented in the modern seas by a number of genera and species which range from shallow water to a maximum depth of about 3000 fathoms. They are gregarious in habit, and usually of very local distribution. A typical crinoid consists of a dorsal cup or *calyx*, placed on a *stalk* or stem, by means of which it is attached, and bears a fringe of *arms*, variously divided and furnished with jointed appendages, or *pinnules*. The calyx is composed of a number of plates, which have a definite arrangement, in horizontally disposed series (fig. 50). The lowest of these are the *basals*, though in many forms an additional series, the *infrabasals*, may underlie and alternate with the basals. Next above the basals, and alternating with them in position, are the *radials*, five in number, so called because they are in line with the rays or arms. Referring the position of the inferior plates to that of the radials, we find that the basals are always situated *interradially*, while the infrabasal are situated *radially*. Above the radials lie the *brachials*. These vary greatly in number and kind, sometimes articulating directly with the radials, in which case all the brachials are free, and sometimes having their lower series fixed and immovable, thus forming a part of the calyx. The brachials lying directly on the radials are the *costals;* of these there may be one or more series, when they are distinguished from below as *primary* ($cost.^1$), *secondary* ($cost.^2$), etc. The uppermost costal of each ray is commonly axillary, i. e. pentagonal in outline, with two upper joint edges inclined from each other. On these rest the *distichals*, of which there are 10 in each series. Secondary distichals ($dist.^2$) may rest on the primary ones ($dist.^1$), and may in turn support the *palmars*, of which there would be 20 in a normal series. Above these, on farther division, are the *post-palmars*, which are often very numerous. Two types of arms can be distinguished, those composed throughout of one series of plates (uniserial), and those made up of a double series (biserial), the plates of the latter usually interlocking to a greater or less extent. The latter are the more specialized, always beginning uniserially.

Between the radials are often found additional plates, the *interradials*, which may vary in number.

Between the distichals of one ray may occur the *interdistichals*, which are situated *radially*. Between the distichals of adjacent rays may occur the *interbrachials*, and these will be situated *interradially*.

An anal interradius is present in unsymmetric forms. The *tegmen* forms the cover, or ventral part of the calyx, and is composed of plates either closely ankylosed, or held together by a leathery membrane. In the Paleozoic Camerata the plates of the ventral disk fit closely and they are considerably thickened, forming a very rigid, more or less convex vault, from which may rise the plated anal proboscis.

The mouth of Paleozoic camerate crinoids lies beneath the tegmen, the only external opening being that of the anus. From the mouth, radiating grooves or canals commonly pass outward to the arms, in which they are continued. These are the ambulacral grooves, along which the food, caught on the arms, is conveyed to the central mouth. These grooves may be open or covered by plates. Within the cavity of the calyx are the viscera.

The stalk, or *stem*, is composed of a varying number of joints, which are circular, elliptic or angular in cross-section (fig. 52). The joint nearest to the calyx is the last formed except in the Flexibilia. Frequently a certain number of the joints bear root-like extensions or *cirri*. The stem and cirri are pierced by an axial canal, round or pentagonal in cross-section. The stem was in most cases attached by a root. Some crinoids were without a stem, having been attached by the base directly or more rarely being free-swimming organisms.

Order LARVIFORMIA Wachsmuth & Springer

Genus STEPHANOCRINUS Conrad

[Ety. *στέφανος*, a crown; *κρίνον*, a lily]

(1842. *Acad. nat. sci. Phil. Jour.* 8:278)

Calyx cup-shaped, composed of three elongate basals, five radials, and five interradials. Radials deeply forked; the prongs formed by the margins of two continuous radials extending upward between the arms, and building, together with the interradials, a row of five pyramids, near the summit of one of which is situated the anal aperture. Radial incisions occupied by the ambulacral grooves, which are roofed over by two rows of covering pieces; those of the same row closely ankylosed. First costals semilunate, and resting within a horseshoe-like concavity near the outer end of the radial incisions. Tegmen constituted of five large triangular *oral plates*. Arms very short,[1] composed of about 10 pieces, all of which are axillary and give off side arms. The latter are biserial, non-pinnu-

[1] Generally wanting in the weathered-out specimens.

late, and are made up of long, strongly cuneiform joints. Stem consisting of circular joints pierced by a circular axial canal.

Stephanocrinus angulatus Conrad (Fig. 48) (Hall. 1852. *Pal. N. Y.* 2:212, pl. 48, 83)

Distinguishing characters. Thick, equal stem joints, with crenulated, articulating margins, and minute round canal; form of calyx

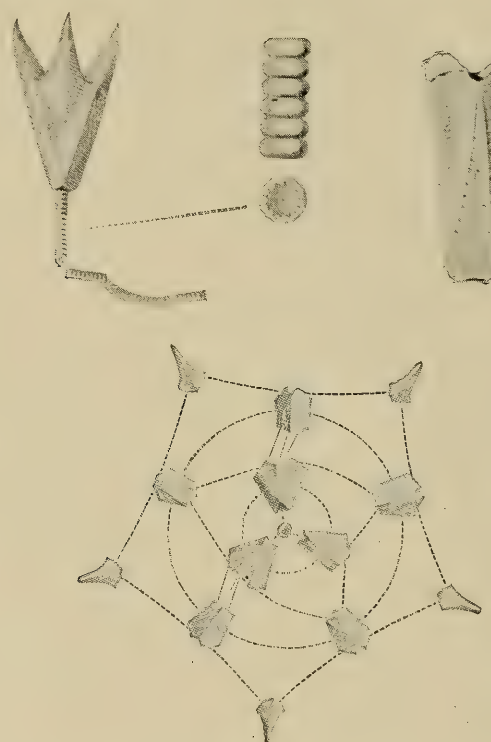


Fig. 48 Stephanocrinus angulatus with an enlargement of the stem and an analysis of the calyx

reverse pyramidal, gradually spreading from a triangular base upward; sutures scarcely visible; three basals, one pentagonal and two heptagonal; radials hexagonal with short excavated upper side; interradials broad below, contracting upward to form the coronal points; strong and angular carinae, six of which alternately converge upward and downward, while two others, somewhat stronger, extend from the bases of the heptagonal basals to the summit of the radials immediately succeeding; elevated tuberculated striae of the plates which extend transversely, vertically or obliquely on different parts of the calyx; surface sometimes merely tuberculated.

Found in certain thin calcareous layers of the lower Rochester shale at Niagara, sometimes quite abundantly. Also in the same shale at Lockport (Hall). The crinoid is generally much lighter in color than the inclosing rock, and is easily distinguished. Associated

with Eucalyptocrinus fragments and other crinoids, as well as other fossils.

Stephanocrinus gemmiformis Hall (Fig. 49) (1852. *Pal. N. Y.* 2:215, pl. 48)

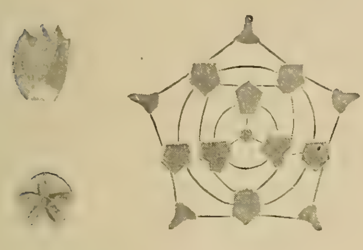


Fig. 49 Stephanocrinus gemmiformis with analysis of calyx

Distinguishing characters. Sharply triangular base; rapidly enlarging calyx, which is rotund in the middle and slightly contracted toward the summit. Upper margin of radials scarcely depressed or excavated; granular noncarinate surface of plates; slightly converging coronal processes.

Found in the Rochester shale at Lockport (Hall). Probably also at Niagara.

Order CAMERATA Wachsmuth & Springer

Genus THYSANOCRINUS Hall

[Ety.: θύσἄνος, fringe; κρίνον, lily]

(1852. *Pal. N. Y.* 2:188)

Calyx deep, with a dicyclic base. Infrabasals and basals five each, the former pentagonal, the latter generally hexagonal. Radials

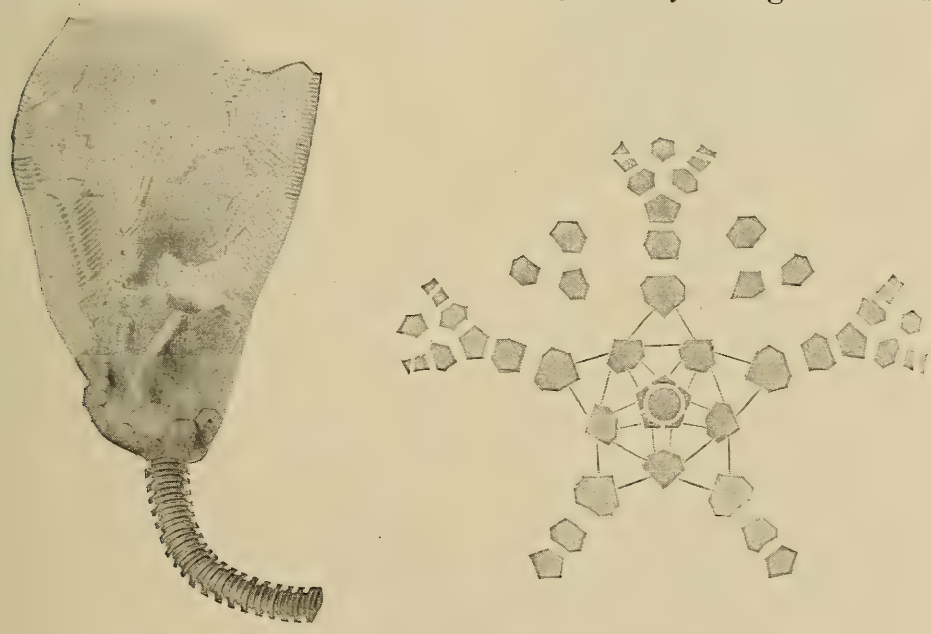


Fig. 50 Thysanocrinus liliiformis with analysis of calyx

five, hexagonal, laterally in contact, except at the azygous side, where they are separated by an anal plate which is succeeded by three in-

terradial plates. Lower brachials forming a part of the calyx; cost.[1] hexagonal, cost.[2] pentagonal, axillary bearing the distichals. Interradials lying chiefly between the costals. Arms 10 to 20, biserial. Stem round.

Thysanocrinus liliiformis Hall (Fig. 50) (1852. *Pal. N. Y.* 2:188, pl. 42)

Distinguishing characters. Surface of plates ornamented by vertical or radiating, interrupted or crenulated, sharp, elevated striae; small infrabasals, large basals and still larger radials; three distichals in each of the 10 arms, the lowest large and hexagonal, the others cuneiform, followed by the biserial upper arm plates; stem joints round and alternatingly thin and thick, most irregular near the base of the calyx.

Fig. 51 Lyriocrinus dactylus

Found so far only in the Rochester shale at Lockport (Hall), but may also occur at Niagara.

Genus LYRIOCRINUS Hall

[Ety : λύριον, small lyre; κρίνον, lily]

(1852. *Pal. N. Y.* 2:197)

Calyx depressed, with a dicyclic base. Infrabasals five; basals five, pentagonal, truncated at the upper end. Radials separated all around by large interradials, which scarcely differ from the anal interradius. Anal aperture eccentric. Plates of the calyx smooth or finely granulose. Tegmen almost flat, composed of a large number of small plates. Arms 10, strong, simple and biserial. Stem round.

Lyriocrinus dactylus Hall (Fig. 51) (1852. *Pal. N. Y.* 2:197, pl. 44)

Distinguishing characters. Stem near the calyx of alternating larger and smaller joints, the larger projecting much beyond the

smaller ones; calyx plates finely ornamented by granules, which become elongated near the margins of the plates; two simple distichals in each arm, abruptly followed by the biserial arm plates.

Found in the talus of the weathered Rochester shale above Lewiston, probably from the thin calcareous beds of the lower part of the shale. Also in the same shale at Lockport (Hall).

Glyptocrinus plumosus Hall (Fig. 52) (1852. *Pal. N. Y.* 2:180, pl. A41)

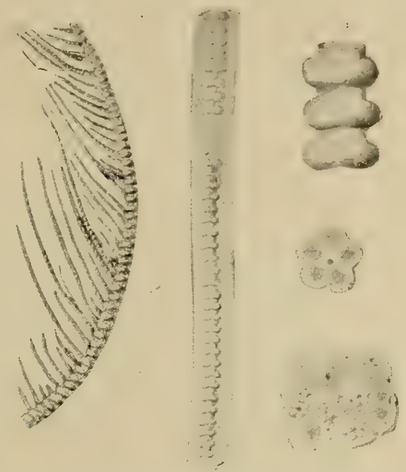


Fig. 52 Glyptocrinus plumosus the arm pinnules and stem with an enlargement of stem joints

Under this name Hall has figured and described fragments of the stem and arms of a crinoid from the Clinton beds of western New York, which he states is extremely rare at Niagara, but often common farther east. The characteristics of these fragments are shown in the illustrations here reproduced.

Genus EUCALYPTOCRINUS Goldfuss

[Ety.: εὖ, well; καλύπτειν, cover; κρίνον, lily]

(1826. *Petrefacta Germaniae,* p. 212)

Calyx with a deep concavity at the lower end, of which the monocyclic base forms the bottom. Calycinal plates having throughout a pentameral arrangement, except the basals, which are only four in number. Radials in contact all around, costals 2 x 5, distichals 2 x 10, and above these the palmars in cycles of 20, and of small size. There are 1 x 5 large interradials, above which are two narrow and elongate interbrachials placed side by side. Between the distichals is in each ray one interdistichal, which has nearly the form and size of the two interbrachials combined. On the interbrachials and interdistichals and the tegmen rest 10 partitions, which extend upward and form compartments which contain two arms each. Arms biserial, composed of very narrow pieces. A proboscis surmounts the tegmen and projects above the arms. Stem round.

Eucalyptocrinus decorus (Phillips) (Fig. 53) (Hall. 1852. *Pal. N. Y.* 2:207, pl. 47)

Distinguishing characters. Stem consisting of alternating thicker and thinner joints, the former wider than the latter, with rounded

edges; two or three thin joints between thick ones; articulating surfaces of joints deeply striated radially from margin nearly to the canal; canal pentapetalous; calyx subcylindric or ovoid, gradually enlarging from base upward to commencement of arms, then diminishing; summit contracted; surface of plates generally smooth.

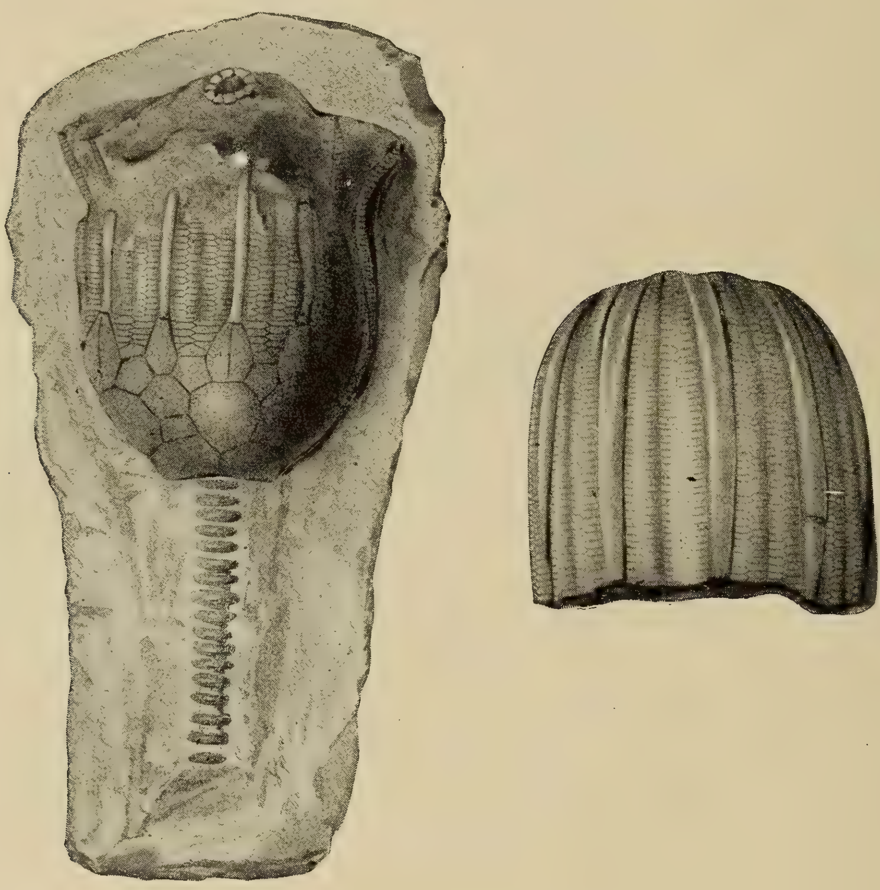


Fig. 53 Eucalyptocrinus decorus

Found in the lenses of limestone in the upper Clinton and in the calcareous beds of the lower Rochester shale, as well as the Bryozoan bed at Niagara. Often plentiful but generally in dissociated plates, of which the interbrachial partition plates are most readily recognized. The " roots " are occasionally found attached to corals, etc. Also represented in the middle and upper limestones at Niagara, but generally replaced. Also in the shale at Lockport and other localities (Hall).

Order FLEXIBILIA Zittel

Genus ICHTHYOCRINUS Conrad

[Ety.: ἰχθύς, fish; κρίνον, lily]

(1842. *Acad. nat. sci. Phil. Jour.* 8:279)

Calyx with all plates above the radials united by loose suture or by muscular articulation. Base dicyclic; infrabasals three, unequal, very small, rarely extending beyond the top stem joint with which they are fused. Basals five, small. Radials and lower brachials laterally in contact on all sides; no interradials or anals. Brachials united by more or less wavy sutures and their lower edges furnished with tooth-like projections which fit into depressions on the subjacent plates. Tegmen squamous, composed of five orals and numerous, very small, movable plates. Arms non-pinnulate, with a wide, shallow ventral groove. When the arms are folded, the crown appears like a perfectly solid body. Stem round, the upper joints extremely short, and generally wider than the others.

Ichthyocrinus laevis Conrad (Fig. 54) (Hall. 1852. *Pal. N. Y.* 2:195, pl. 43)

Distinguishing characters. Stem slender, round and smooth, gradually enlarging to the base of the calyx and composed of alternate thick and thin joints; radials five, succeeded by two to four costals in each radius; 10 columns of distichals, from six to nine plates in each, an unequal number in the two columns of each radius; 20 columns of palmars, and 40 of post-palmars, the number of plates varying in the columns of the same individual; plates with lower margins obtusely triangular and upper margins with a corresponding reentrant angle; axillary plates angular above and below.

Fig. 54 Ichthyocrinus laevis with stem enlarged

Found in certain calcareous layers near the middle of the lower Rochester shales at Niagara. Also in the same shales at Lockport (Hall).

Genus LECANOCRINUS Hall

[Ety.: λεκάνη, basin; κρίνον, lily]

(1852. *Pal. N. Y.* 2:199)

This genus differs from Ichthyocrinus only in having a rhomboidal anal plate separating the two posterior radials, and followed by a somewhat larger anal interradial.

Lecanocrinus macropetalus Hall (Fig. 55) (1852. *Pal. N. Y.* 2:199, pl. 45)

Distinguishing characters. Subglobose calyx; three large infrabasals, the two larger truncated on top; larger basals, two pen-

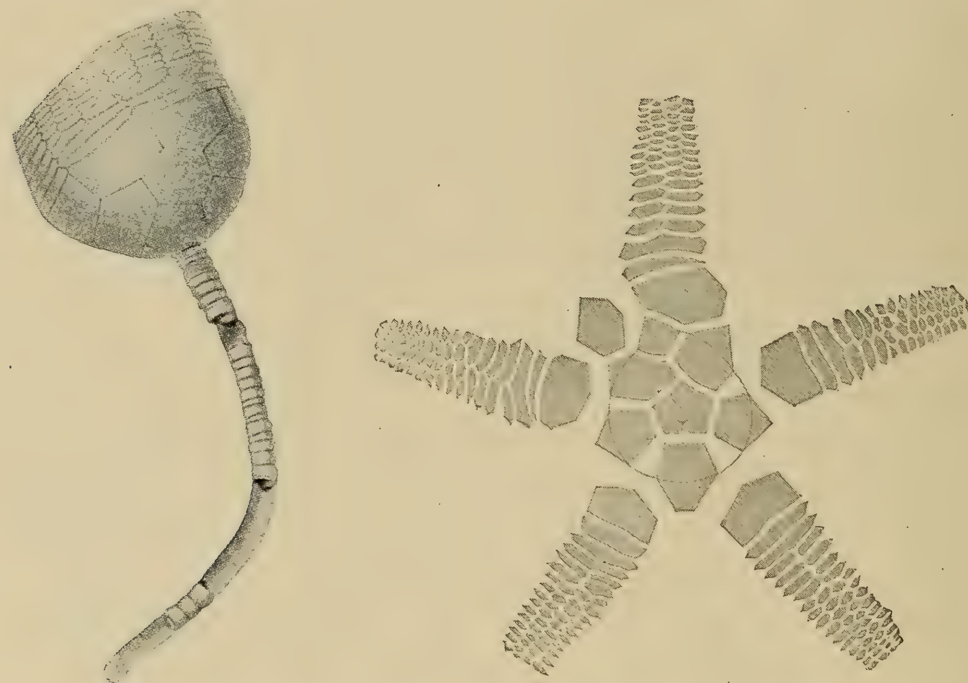


Fig. 55 Lecanocrinus macropetalus with analysis of calyx

tagonal, one hexagonal and two heptagonal; subquadrangular anal plate following on heptagonal basals and succeeded by large interradial plate; large radials, two pentagonal and three with a short sixth side; costals 2 x 5, short, succeeded by distichals and palmars similar to Ichthyocrinus laevis; slender stem; smooth, thick joints alternating at irregular intervals with thin ones, and having slightly rounded edges and a round canal.

Found in the Rochester shale at Lockport (Hall). May also occur at Niagara.

Class ANNELIDA Macleay

The annelids, or typical worms, are soft-bodied, marine, fresh-water or terrestrial animals, whose remains can seldom be preserved in a fossil state. It is only the tube-building order (Tubicola) that leaves any satisfactory remains. In these the tube is either a calcareous secretion of the animal or is composed of agglutinated sand and other foreign particles, being, in each case, wholly external. Worm burrows are often preserved by sand or mud infiltration, a cast of the burrow appearing in the strata.

Genus CORNULITES Schlotheim

[Ety.: *cornu*, horn; λίθος, stone]

(1820. Schlotheim. *Petrefactenkunde*, p. 328)

Tube gently tapering, flexuous, the small end usually bent. The tube is either wholly or in part adherent to other objects. Walls thick, cellular, composed of imbricating rings. Surface ornamented by annulations and longitudinal striae. Interior presenting a succession of annular constrictions, giving a scalariform character to the cast.

Fig. 56 Cornulites bellistriatus

Cornulites bellistriatus Hall (Fig. 56) (1852. *Pal. N. Y.* 2:353, pl. 85, fig. 13-17, and v. 7, supplement, p. 20, pl. 116A, fig. 12, 13)

Distinguishing characters. Wall thick; annulations slightly marked at base, less strongly and irregularly marked in upper portion; fine longitudinal striae well marked throughout.

Found in the talus of Rochester shale, along the Rome, Watertown and Ogdensburg railroad above Lewiston hights.

Class BRYOZOA Ehrenberg

The Bryozoa, or Polyzoa, are marine or fresh-water invertebrates, almost always occurring in colonies or zoaria which increase by gemmation. Each *zooid* of the colony is inclosed in a membranaceous, or calcareous, double-walled sac, the *zooecium*, into which it can withdraw. The animal possesses a mouth, an alimentary canal and an anal opening, and, in addition to these, a fringe of respiratory

tentacles—the *lophophore.* The colony is commonly attached to foreign bodies, which it either incrusts or from which it arises as an independent frond.

In the Paleozoic genera the cell apertures are often surrounded by elevated rims, or *peristomes.* In many forms a portion of the posterior wall of the tube is more or less thickened, and curved to a shorter radius, often projecting above the plane of the aperture. This forms the *lunaria,* and their ends may project into the tubes as *pseudosepta.* In the interapertural space may occur angular or irregular cells, the *mesopores,* while on many portions of the surface, tubular spines (*acanthopores*), or nodes (rounded, knob-like elevations), may occur. At intervals, in many genera, rounded elevations, or *monticules,* are found, which may, or may not, be destitute of cells. *Maculae* or irregular blotches, destitute of cells, also occur in many forms. Some species bear a superficial resemblance to certain corals, particularly the monticuliporoids.

Genus DIPLOCLEMA Ulrich

[Ety.: διπλόος, double; κλῆμα, twig]

(1890. *Geol. sur. Illinois,* 8:368)

Zoarium dendroid, branches slightly compressed, spreading in the same plane; zooecia tubular, diverging from a wavy mesial mesotheca; apertures circular; prominent.[1]

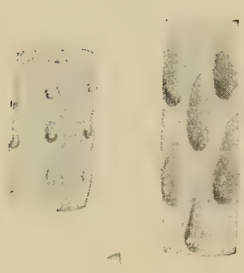


Fig. 57 Diploclema sparsa enlargements of fresh and worn branches

Diploclema sparsa (Hall) (Fig. 57). Trematopora sparsa Hall (1852. *Pal. N. Y.* 2:155, pl. 40A, fig. 12a-d)

Distinguishing characters. Slender, cylindric bifurcating stems; distant cells, opening obliquely upward; elongated nariform calicles.

Found abundantly in the Rochester shale at Lockport (Hall) probably also at Niagara.

Genus CERAMOPORA Hall

[Ety.: κέραμος, a tile; πόρος, pore]

(1852. *Pal. N. Y.* 2:168)

Zoarium disk-like, free or attached by the center of the base; under surface with one or more layers of small, irregular cells; zooe-

[1] The generic descriptions of the Bryozoa are adapted or transcribed from Nickles & Bassler; Synopsis of American fossil Bryozoa. U. S. geol. sur. Bul. 173. I have also followed these authors in the synonomy of the species.

cia tubular, radiating on the upper surface from a depressed center; apertures oblique, imbricating, provided with a lunarium; mesopores short, irregular, decreasing in number from center to margin; large maculae or clusters of mesopores or of zooecia at regular intervals.

Ceramopora imbricata Hall (Fig. 58) (1852. *Pal. N. Y.* 2:169, pl. 40E, fig. 1a-i)

Distinguishing characters. Depressed hemispheric form, flattened or convex on the lower side; composed of cylindric or subcylindric tubes slightly diverging from the center, rectangular to plane of upper surface; arched or triangular aperture, opening on all sides toward the outer margin, arranged in alternating and imbricating series.

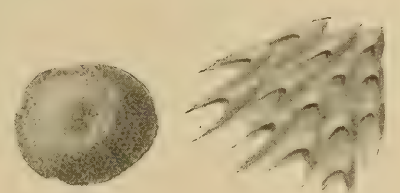


Fig. 58 Ceramopora imbricata with enlargement of surface

Found in the Rochester shale at Lockport (Hall) and probably also at Niagara.

Ceramopora incrustans Hall (Fig. 59) (1852. *Pal. N. Y.* 2:169, pl. 40E, fig. 2a-d)

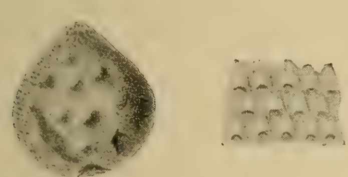


Fig. 59 Ceramopora incrustans with enlargement of surface

Distinguishing characters. Incrusting habit; cells increasing unequally from a center or point of growth, short, minute, opening obliquely outward and arranged in quincunx order.

Found in the Rochester shale at Lockport (Hall); may also occur at Niagara.

Genus CHILOTRYPA Ulrich

[Ety.: χεῖλος, lip; τρῦπα, perforation]

(1884. *Cin. soc. nat. hist. Jour.* 7:49)

Zoarium small, branching, with a narrow, irregularly contracting and expanding tube; zooecial tubes cylindric or somewhat compressed, thin walled, with or without diaphragms; walls minutely porous; apertures elliptic, oblique, the lower margin thickened and elevated; at irregular intervals maculae or monticules, composed of clusters of vesicles and of zooecia slightly larger than the average occur; interzooecial spaces occupied by vesicular tissue, which is commonly filled by a dense calcareous deposit near the surface.

Chilotrypa ostiolata (Hall) (Fig. 60). Trematopora ostiolata Hall (1852. *Pal. N. Y.* 2:152, pl. 40A, fig. 5a-n)

Distinguishing characters. Irregularly branching cylindric stems gradually tapering toward the extremities, which are obtuse; aper-

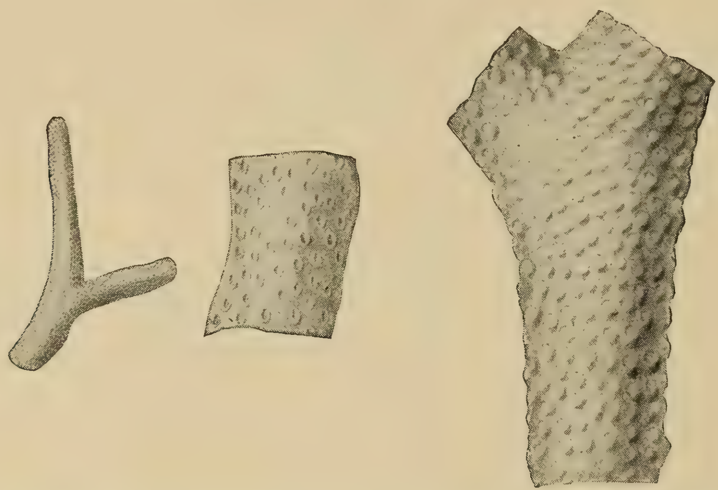


Fig. 60 Chilotrypa ostiolata; branch natural size and two enlargements

tures about their diameter apart, arranged in spirally ascending lines or irregularly; strong peristomes; interapertural spaces smooth; stems solid or incrusting crinoids.

Found abundantly in the Bryozoa beds of the Rochester shale and in some of the calcareous layers below it in the Niagara sections. Also at Lockport, etc. (Hall).

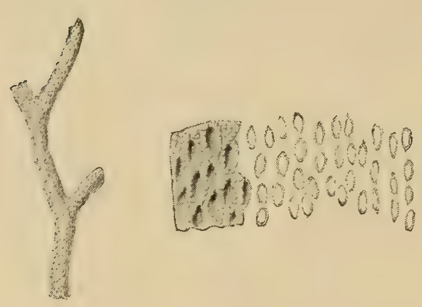


Fig 61 Batostomella granulifera with enlargement of part of surface

Genus BATOSTOMELLA Ulrich

[Ety.: βάτος, bramble; στόμα, mouth]

(1882. *Cin. soc. nat. hist. Jour.* 5:154)

Zoarium ramose, branches slender; zooecia with thick walls in the mature region and with few diaphragms in the peripheral region, often centrally perforated; apertures small, circular or oval; interspaces rounded or canaliculate, spinulose; acanthopores small and usually very numerous; mesopores small, with subcircular openings.

Batostomella granulifera (Hall) (Fig. 61). Trematopora granulifera Hall (1852. *Pal. N. Y.* 2:154, pl. 40A, fig. 9a-e)

Distinguishing characters. Slender branches; oval to elongate apertures, margined by wavy, raised, granulose lines, which are double between the cells.

Found rarely in the lower Rochester shale, associated with Ichthyocrinus and other rare fossils. Niagara sections. Also in the same shale at Lockport (Hall).

Genus LIOCLEMA Ulrich

[Ety.: λεῖος, smooth; κλῆμα, twig]

(1882. *Cin. soc. nat. hist. Jour.* 5:141, 154)

Zoarium ramose, lamellar, subglobose or incrusting; surface frequently exhibiting distinct monticules or maculae; zooecia with subcircular or irregularly petaloid apertures, separated by abundant angular mesopores, which in some species are open at the surface, in others closed; diaphragms few in the zooecia, abundant, sometimes crowded in the mesopores; acanthopores numerous and strong in the typical species, small and inconspicuous in others.

Lioclema florida (Hall) (Fig. 62). Callopora florida Hall (1852. *Pal. N. Y.* 2:146, pl. 40, fig. 2a-f)

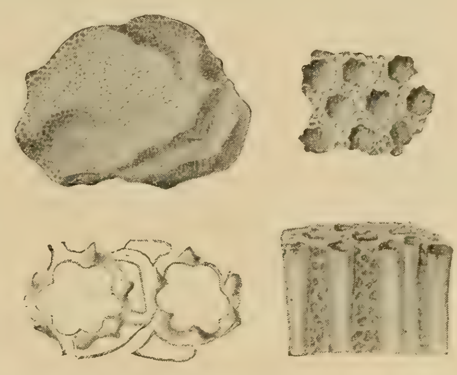


Fig. 62 Lioclema florida with side and summit views enlarged, and two calyxes much enlarged

Distinguishing characters. Explanate or incrusting habit; tubular cells; floriform apertures the margins of which appear as if formed of segments of six or seven smaller curves; each angle of aperture furnished with spine (acanthopore); mesopores angular in perfect specimens.

Found in the Bryozoa beds of the Rochester shales at Niagara, rare. Also at Lockport (Hall).

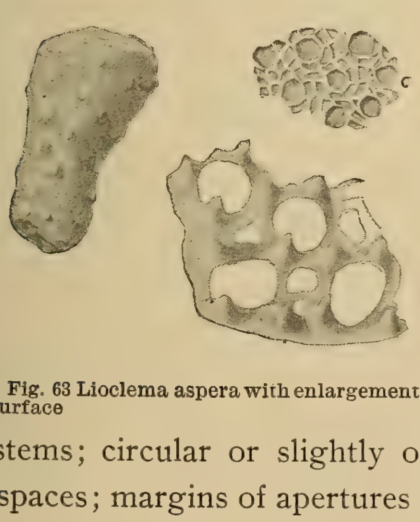


Fig. 63 Lioclema aspera with enlargements of surface

Lioclema aspera (Hall) (Fig. 63). Callopora aspera Hall (1852. *Pal. N. Y.* 2:147, pl. 40, fig. 4a-i)

Distinguishing characters. Stems solid or hollow cylinders, often also incrusting other bodies in broad, explanate or foliate expansions; clavate or thickened extremities of stems; circular or slightly oval apertures; finely reticulated interspaces; margins of apertures surrounded by minute points (acantho-

pores) which give the entire surface an asperato-granular appearance.

Found in the Rochester shale at Lockport (Hall), and probably also at Niagara.

Genus BYTHOPORA Miller & Dyer

[Ety.: βυθός, depth; πόρος, pore]

(1878. *Contrib. to paleontology* no. 2, p. 6)

Fig. 64. Bythopora spinulosa enlarged

Zoarium usually with slender branches, sometimes of considerable size; diaphragms obsolete; apertures oblique, narrowing above; interspaces canaliculate; mesopores few; acanthopores strong, rarely more than one to each zoarium, sometimes wanting.

Bythopora spinulosa (Hall) (Fig. 64). *Trematopora spinulosa* Hall (*Pal. N. Y.* 2:155, pl. 40A)

Distinguishing characters. Oval apertures; cylindrical branches; strong spines (acanthopores) arranged at nearly regular intervals.

Found in the Rochester shale at Lockport. (Hall) Probably occurs also at Niagara.

Genus TREMATOPORA Hall

[Ety.: τρῆμα, foramen; πόρος, pore]

(1852. *Pal. N. Y.* 2:149)

Zoarium ramose; surface smooth or with monticules; zooecia thin-walled, the contact lines of walls of adjoining zooecia distinct; diaphragms few, in the proximal ends of the zooecia; apertures circular or oval, with a more or less well marked peristome; interspaces solid; mesopores irregularly angular, often obscurely moniliform, with diaphragms at the constricted parts; acanthopores of medium or small size usually present.

Trematopora tuberculosa Hall (Fig. 65) (1852. *Pal. N. Y.* 2:149, pl. 40A, fig. 1a-g)

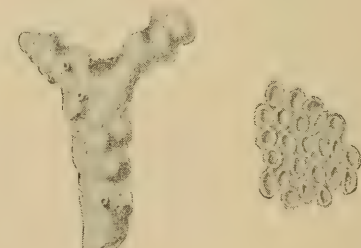


Fig. 65 Trematopora tuberculosa with enlargement of surface

Distinguishing characters. Irregularly ramose and stout branches; tuberculous monticules; tubular cells with oval apertures and thin elevated calicle or margin which is spinulose (bearing acanthopores); interapertural spaces solid, but septate below.

Found abundantly in the Bryozoa beds of the Rochester shales, at Niagara, also at Lockport (Hall).

Trematopora (?) striata Hall (Fig. 66) (1852. *Pal. N. Y.* 2:153, pl. 40A, fig. 7a-d and 8a-b)

Distinguishing characters. Expanded at the base; strongly striated; slender, cylindric, scarcely tapering branches; oblong oval apertures distant from each other about the width of the aperture; interapertural space with continuous groove.

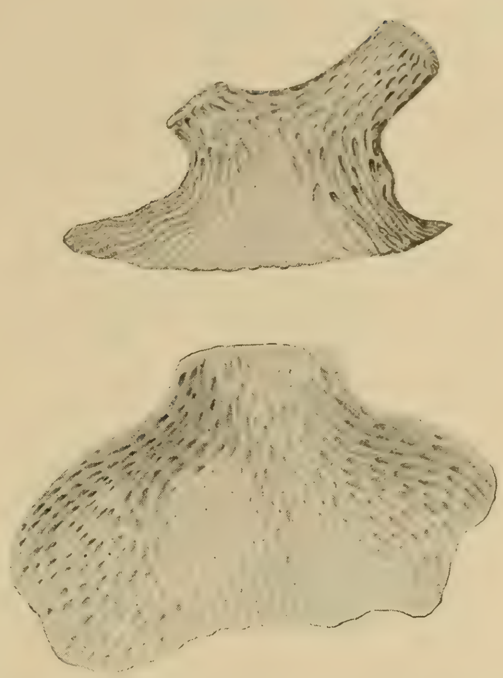


Fig. 66 Trematopora (?) striata much enlarged

Found in the Rochester shale at Lockport (Hall), probably also at Niagara.

Genus CALLOPORA Hall

(emend. Ulrich)

[Ety.: κάλλος, beauty; πόρος, pore]

(1852. *Pal. N. Y.* 2:144)

Zoarium usually ramose, the branches frequently anastomosing and forming bushy clumps; zooecia at first prismatic, four to eight sided, gradually becoming cylindric in most cases; at first with closely set diaphragms, becoming more distant, finally in the mature region usually closely set; apertures closed at times by perforated, often ornamental covers; mesopores more or less numerous, angular, crowded with diaphragms. No acanthopores.

Callopora elegantula Hall (Fig. 67) (1852. *Pal. N. Y.* 2:144, pl. 40, fig. 1a-m)

Distinguishing characters. Cespitose or fruticulose groups of small stems frequently branching; branches bifurcating or variously diverging from the stem; solid; extremities often hollow or cup-like indentations, also blunt; apertures circular, the opercula or covers

with a central perforation from which radiate a number of ridges, giving the cells often a radiately septate appearance; mesopores single, in groups or encircling the apertures.

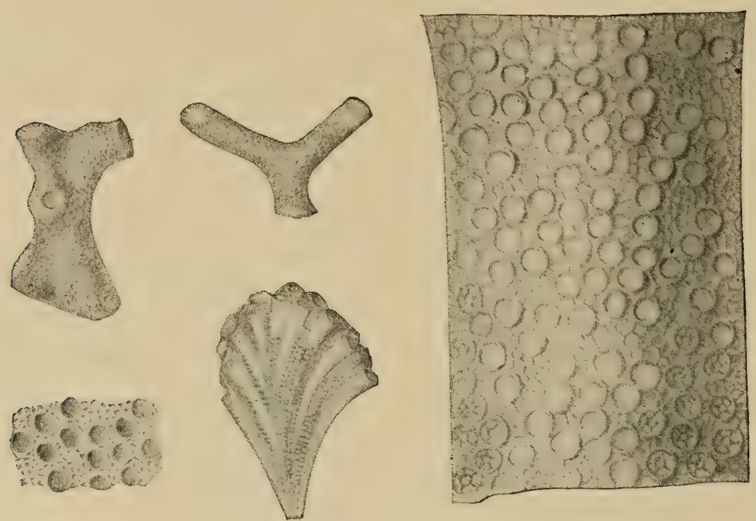


Fig. 67 Callopora elegantula with enlargements of surface, and individual tubes

Found abundantly in the Bryozoa beds of the Rochester shale at Niagara. Also common at Lockport (Hall).

Genus PHYLLOPORINA Ulrich

[Ety.: φύλλον, leaf; πόρος, pore]

(1890. *Geol. sur. Illinois*, 8:399, 639)

Zoarium branching, with branches irregularly anastomosing, with two to eight rows of apertures on one side, longitudinally striated

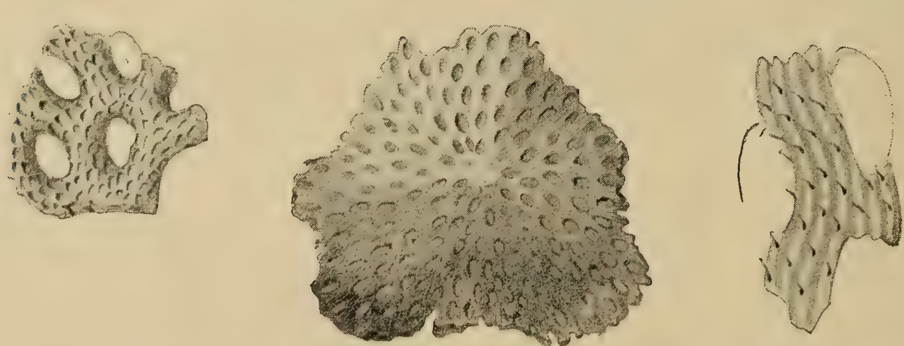


Fig. 68 Phylloporina asperato-striata with enlargement of celluliferous and non-celluliferous faces, the latter showing the asperate-striate character

on the other; zooecia more or less tubular, often with diaphragms, and generally separated by tabulated interstitial spaces, which are closed at the surface; acanthopores often present.

Phylloporina asperato-striata (Hall) (Fig. 68). Retepora asperato-striata Hall (1852. *Pal. N. Y.* 2:161, pl. 40C, fig. 2a-h)

Distinguishing characters. Network of anastomosing branches, with oval interstices which are somewhat unequal; outer face roughly striate; inner face poriferous; three, four or more rows of oval or subangular cells arranged somewhat in oblique parallel lines or in quincunx order; apertures in perfect specimens probably with peristomes.

Found abundantly in the Bryozoa beds of the Rochester shale at Niagara. Generally adhering to the shale laminae by the celluliferous face. Also at Lockport (Hall).

Genus DRYMOTRYPA Ulrich

[Ety.: δρυμός, coppice; τρῦπα, perforation]

(1890. *Geol. sur. Illinois.* 8:399)

Zoarium branching dichotomously at frequent intervals; zooecia in several ranges, tubular, opening on one side only and springing from a thin double plate, beneath which a number of vesicles are

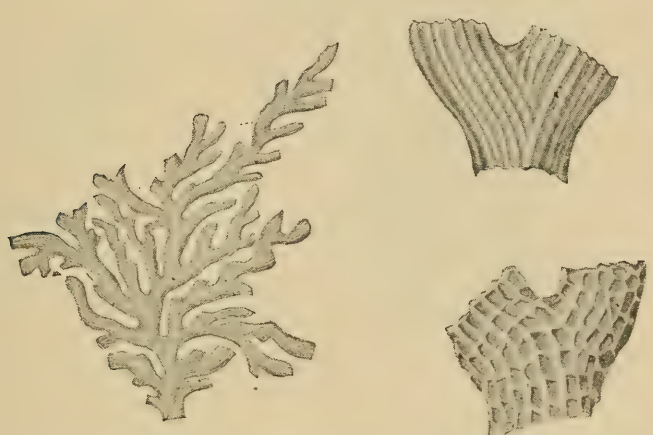


Fig. 69 Drymotrypa diffusa with celluliferous and non-celluliferous sides enlarged

present; reverse side longitudinally striated; vestibules expanding from the orifices to the angular apertures.

Drymotrypa diffusa (Hall) (Fig. 69) Retepora diffusa Hall (1852. *Pal. N. Y.* 2:160, pl. 40C, fig. 1a-f)

Distinguishing characters. Shrubby form, several stems originating from a common base; stems frequently bifurcating and spreading laterally, forming a broad frond; stems and branches cellulifer-

ous on one side only, deeply striated longitudinally on the other; quadrangular or subrhomboidal apertures; branches often thickened or clavate, always obtuse.

Found in the upper part of the lower Rochester shale and the Bryozoa beds at Niagara. Rare. Also at Lockport (Hall).

Genus FENESTELLA Lonsdale

[Ety.: *fenestella*, a little window]

(1839. Murchison. *Silurian system*, p. 677)

Zoarium consisting of a calcareous branching frond, forming cup-shaped or funnel-shaped expansions. The branches fork, and are connected by transverse bars or dissepiments, thus inclosing spaces or fenestrules. The cell apertures occur only on the inner side of

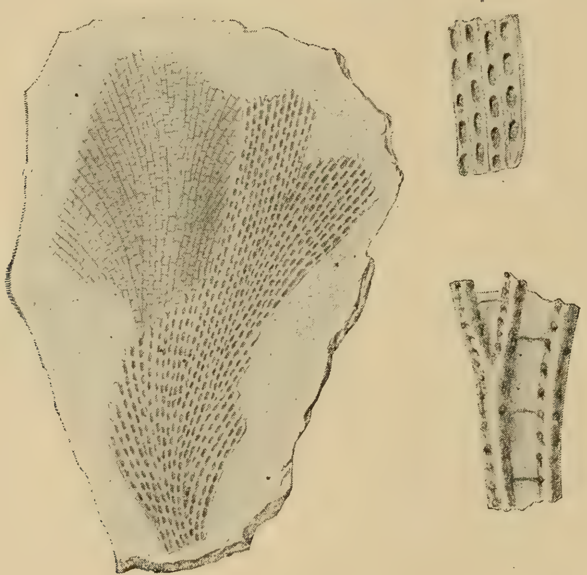


Fig. 70 Fenestella elegans with enlargements

the branches. They are surrounded by rims or peristomes and are arranged in two parallel rows, while between them occurs a ridge (carina) or a row of nodes.

Fenestella elegans Hall (Fig. 70) (1852. *Pal. N. Y.* 2:164, pl. 40D, fig. 1a-g)

Distinguishing characters. Carina subdued; apertures with their longer diameter oblique to the direction of the branches; branches slender, frequently bifurcating; thin and slender dissepiments scarcely enlarging at the junction with the branches; fenestrules on

non-celluliferous side oblong, quadrangular, rarely oval; branches finely striate.

Found in the Bryozoa bed of the Rochester shale at Niagara. Also in the same rock at Lockport and elsewhere (Hall).

Genus SEMICOSCINIUM Prout

[Ety.: *semi*, half (somewhat like); κόσκινον, sieve; Coscinium, a genus of Bryozoa]

(1859. *St Louis acad. sci. Trans.* 1:443)

Zoarium funnel-shaped, celluliferous on the outer side; dissepiments wide, very short, the branches appearing to anastomose on the non-poriferous face, where the fenestrules are subrhomboidal or rounded. Apertures in two rows, with a very high median keel, which is expanded at the summit.

Semicoscinium tenuiceps (Hall) (Fig. 71, 72). Fenestella tenuiceps Hall (1852. *Pal. N. Y.* 2:165, pl. 40D, fig. 2a-h) Fenestella prisca? Hall (1852. *Pal. N. Y.* 2:50, pl. 19, fig. 4a-m)

Distinguishing characters. Carina sharp and thin; transverse dissepiments not extending as high as the branches, sometimes scarcely

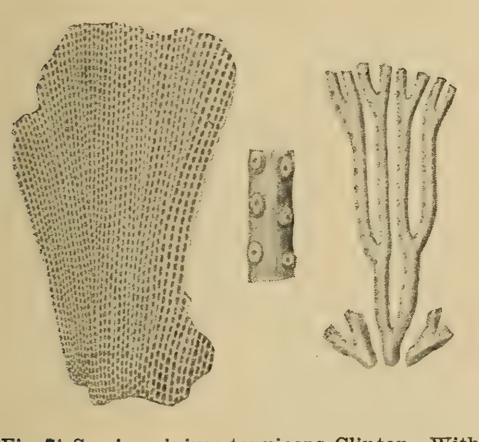


Fig. 71 Semicoscinium tenuiceps, Clinton. With enlargements

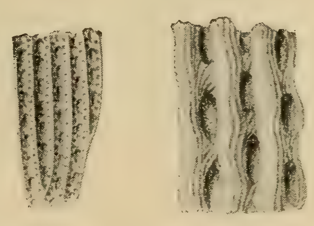


Fig. 72 Semicoscinium tenuiceps, Niagara. Enlargements of celluliferous and non-celluliferous faces

visible; round large apertures opening laterally so as to be scarcely visible when looking down on the frond; non-celluliferous side with oval fenestrules, branches on non-celluliferous side striate, appearing granular when worn.

Found in the Bryozoa beds of the Rochester shales at Niagara; also at Lockport (Hall) (?). It also occurs in the Clinton beds at Lockport, and probably also at Niagara.

Genus POLYPORA McCoy

[Ety.: πολύς, many; πόρος, pore]

(1845. *Synopsis Carbon. foss. Ireland*, p. 206)

Zoarium as in Fenestella, but with from two to eight rows of zooecia on a branch, and without median keel, but sometimes with a row of strong nodes or tubercles.

Polypora incepta Hall (Fig. 73) (1852. *Pal. N. Y.* 2:167, pl. 40D, fig. 5a-f)

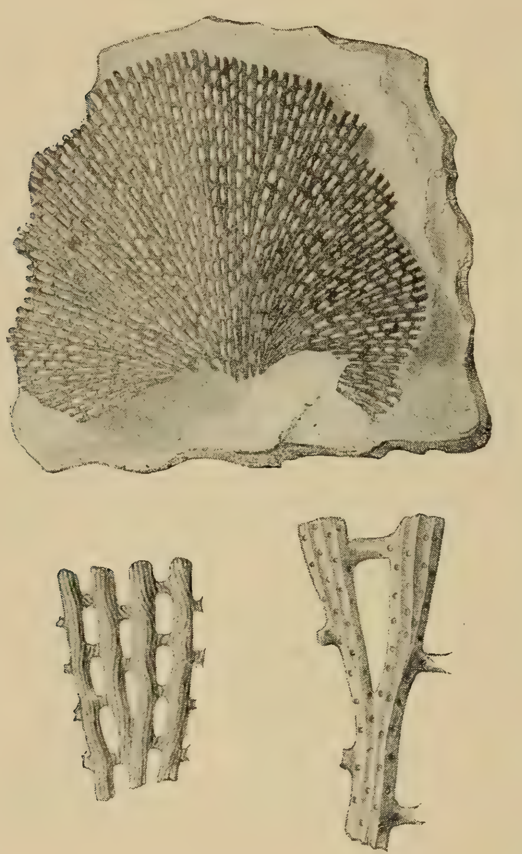


Fig. 73 Polypora incepta with non-celluliferous and celluliferous faces enlarged

Distinguishing characters. Funnel-shaped, but generally compressed form; branches dividing somewhat regularly, sometimes anastomosing; dissepiments at regular intervals, slender, scarcely thickened at their junction with branches; fenestrules oblong, quadrangular, rarely oval; non-celluliferous face longitudinally striate; three or four rows of cell apertures, oval and alternating; dissepiments thinner on celluliferous than on non-celluliferous face; sometimes expanding at the junction with the branches; non-celluliferous face indistinguishable from Fenestella.

Found abundantly in the Bryozoa beds of the Rochester shale at Niagara, and the talus of the cliff above Lewiston hights. Also in the shale at Lockport (Hall).

Genus HELOPORA Hall

[Ety.: ἧλος, nail; πόρος, pore]

(1852. *Pal. N. Y.* 2:44)

Zoarium bushy, dichotomously branching, the whole consisting of numerous slender, equal segments, united by terminal articula-

tions; zooecia subtubular, more or less oblique, radially arranged about a central axis and opening on all sides of the segments.

Helopora fragilis Hall (Fig. 74) (1852. *Pal. N. Y.* 2:44, pl. 18, fig. 3a-f)

Distinguishing characters. Minute cylindric or clavate zoarium swollen at one end; oval or subangular pores, having a spiral direction around the stipe and arranged between longitudinal elevated lines.

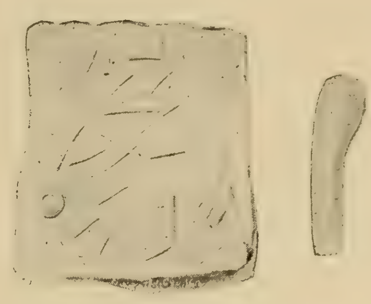


Fig. 74 Helopora fragilis natural size and enlarged

Found in the Clinton beds at Lockport etc. (Hall). Probably occurs also at Niagara. Also abundant in the thin calcareous upper Medina layers at Niagara (?).

Genus CLATHROPORA Hall

[Ety.: *clathri*, a lattice; *porus*, a pore]

Zoarium composed of anastomosing branches, forming a regular network with round or oval spaces or fenestrules, with a pointed,

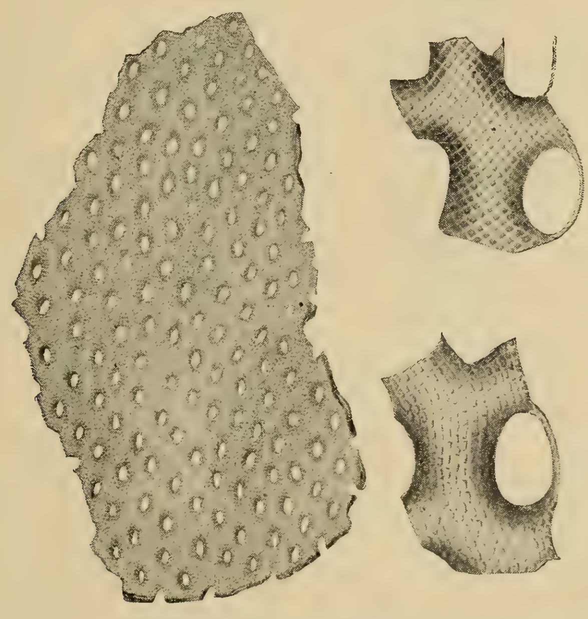


Fig. 75 Clathropora frondosa with portions of celluliferous face enlarged

articulating base; the branches are made up of two layers grown together back to back, and with the zooecial tubes opening on both sides of the frond; apertures usually subquadrate, arranged longitudinally.

Clathropora frondosa Hall (Fig. 75) (1852. *Pal. N. Y.* 2:160, pl. 40B, fig. 5a-e)

Distinguishing characters. Reticulate, expanded, flabellate or funnel-shaped frond, both surfaces regularly and equally celluliferous; apertures rhomboidal or oblong quadrangular, opening obliquely upward.

Found in the Rochester shale at Lockport (Hall) and probably also at Niagara.

Clathropora alcicornis Hall (Fig. 76) (1852. *Pal. N. Y.* 2:159, pl. 40B, fig. 4a-c)

Distinguishing characters. Cylindric branches, bifurcating and variously branched; entire surface celluliferous; apertures quad-

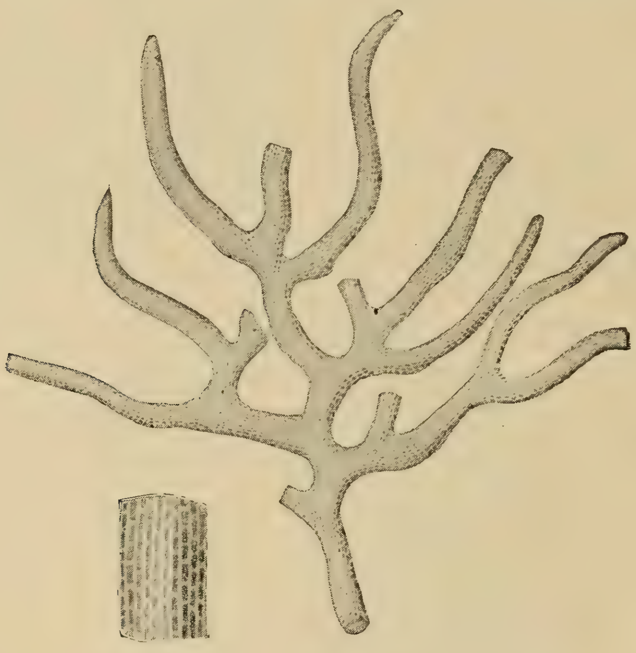


Fig. 76 Clathropora alcicornis with enlargement

rangular, rhomboidal or oblong and variable in form at the division of the stem.

Found in the lower Rochester shale up to and in the Bryozoa bed at Niagara. Rare. Also at Lockport (Hall).

Genus RHINOPORA Hall

[Ety.: ῥινός, hide; πόρος, pore]

(1852. *Pal. N. Y.* 2:48)

Zoarium forming large, undulating bifoliate expansions, celluliferous on both sides; surface usually smooth, rarely with solid

monticules, and traversed by slender, rounded, bifurcating ridges, which appear as shallow grooves when the surface is worn; apertures nearly circular, occupying the summits of prominent papillae; mesopores present, but closed at the surface; large median tubuli in the middle layer or *mesotheca*.

Rhinopora tuberculosa Hall (Fig. 77) (1852. *Pal. N. Y.* 2:170, pl. 40E, fig. 4a-c)

Distinguishing characters. Lamellose or explanate palmate fronds; asperate and tuberculous surface; tubercles mostly destitute of cells at the summit; cells rising in pustules on the surface and opening by roundish oval or tripetalous apertures.

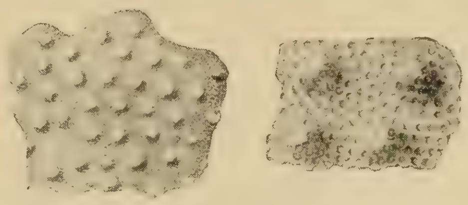


Fig. 77 Rhinopora tubercolosa with enlargement

Found in the Rochester shale at Lockport (Hall) and probably also at Niagara.

Genus DIAMESOPORA Hall

[Ety.: *διά*, through; *μέσος*, middle; *πόρος*, pore]

(1852. *Pal. N. Y.* 2:158)

Zoarium ramose, of hollow stems lined internally by an epitheca; zooecia simple, hexagonal, or rhomboidal, with an oval orifice in the anterior half, which, with growth, forms a tubular vestibule; aperture with peristomes equally elevated or highest posteriorly; intervestibular spaces compact or horizontally laminated.

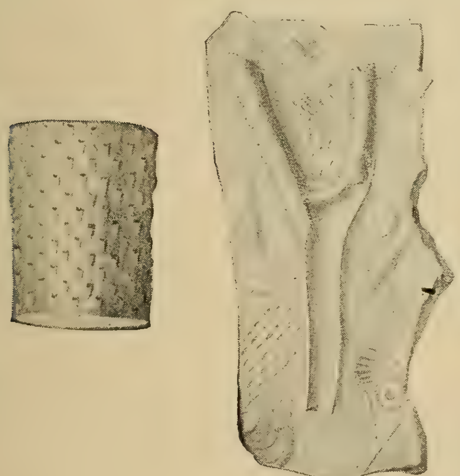


Fig. 78 Diamesopora dichotoma with enlargement

Diamesopora dichotoma Hall (Fig. 78) (1852. *Pal. N. Y.* 2:158, pl. 40B, fig. 3a-d)

Distinguishing characters. Cylindric, hollow, regularly bifurcating stems (a thin crust inclosing inorganic matter); interior of hollow branches transversely striate; cells opening upward in regular ascending or spiral lines; prominent nariform peristomes; stems usually flattened.

Found in the Bryozoa beds of the Rochester shales at Niagara, usually in a crushed condition. Also at Lockport (Hall).

Genus LICHENALIA Hall

[Ety.: λειχήν, lichen]

(1852. *Pal. N. Y.* 2:171)

Zoarium a subcircular expansion, consisting of a single lamina, but often growing in successive layers, the one over the other; zooecia prostrate, elongate subrhomboidal, with a direct, subtubular, outward prolongation or vestibule; apertures rounded, with the peristome much elevated on the posterior side; interspaces depressed.

Lichenalia concentrica Hall (Fig. 79) (1852. *Pal. N. Y.* 2:171, pl. 37A, fig. 2a, b)

Distinguishing characters. Circular frond, slightly cup-form in the young state, flattened at maturity; generally variously contorted from irregular growth or accident, and thick at intervals; concen-

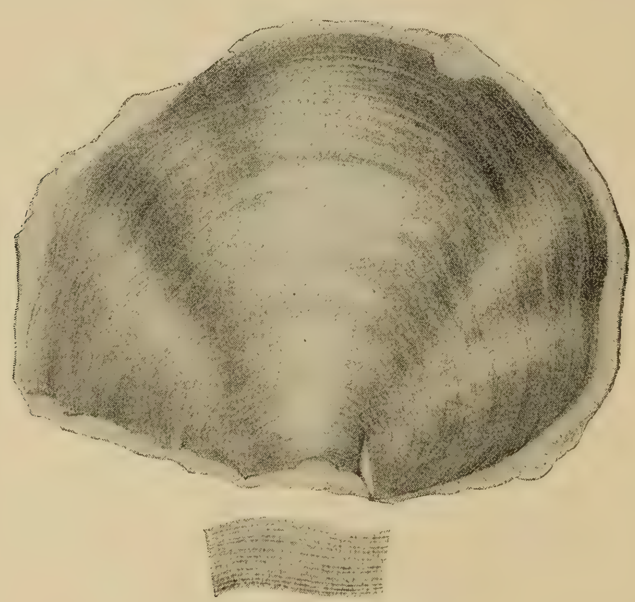


Fig. 79 Lichenalia concentrica

trically striate and rugose surface, strongest on non-celluliferous side; apertures in concentric lines, narrow, opening on the summit of an elevated pustule.

Found rarely in the lower Clinton limestone; abundantly in the Clinton lenses; and again rarely in the lower Rochester shale and the Bryozoa bed. Niagara sections. Also at Lockport and elsewhere (Hall).

Class BRACHIOPODA Cuvier

The Brachiopoda are marine animals, sparingly represented in modern seas, but most prolific in the Paleozoic and early Mesozoic waters.

The valves of the brachiopod shell are dorsal and ventral, and not right and left as in the lamellibranch Mollusca; they are unequal, and each is symmetric with reference to a median line (longitudinal axis) drawn through its apex. The larger valve may have its beak truncated or furnished with an opening or *foramen,* for the emission of the fleshy *pedicle,* by means of which the animal fixes itself to rocks, shells or other substances.

Certain genera, such as Crania, do not conform to this mode of fixation, but cement their shell directly to the foreign object, while others, e. g. Pholidops, appear to have led a free existence. In many of the discinoid genera, such as Orbiculoidea, the pedicle passed through an opening in the lower valve; while in Lingula it protruded between the two very nearly equal valves. In all cases the valve giving emission to the pedicle is spoken of as the *pedicle valve.*

The opposite valve in the more specialized genera bears on its interior two short processes, or *crura,* which arise from the hinge

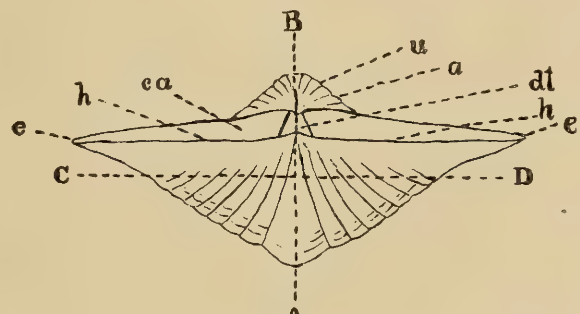


Fig. 80 Diagram of Spirifer. (AB) Longitudinal axis marking the hight; (CD) Transverse axis marking the width; (a) Anterior (front) end; (B) posterior (beak) end; (h) hinge line; (ca) cardina area; (e) cardinal extremities; (dt) deltidium; (u) umbo; (a) apex or beak

plate. To these may be attached a calcareous *brachidium,* which functions as a support for the delicate fleshy " arms ". In a large number of forms this brachidium is absent, and the fleshy arms are directly supported by the crura, but their relation to the valve in question is similar to that obtaining in the brachidium-bearing forms. This valve is designated the *brachial* valve. In all the forms in which the valves are articulated with each other (Brachiopoda articulata) such articulation is produced by *teeth* arising from the pedicle valve and lodged in *sockets* in the brachial valve. The beak of the brachial valve is commonly furnished with a more or less pronounced *cardinal process,* which, at its

free end, presents a surface for the attachment of the *diductor*, or opening muscles, the opposite ends of which are attached near the center of the pedicle valve, where they often leave pronounced *scars*. A contraction of these muscles pulls on the cardinal process, and draws the beak of the brachial valve toward the interior of the pedicle valve, and thus opens the valves. *Adductor* muscles passing from valve to valve and also commonly leaving scars, close the valves again. Below the cardinal process and often merged with it, is an elevated hinge plate whose surface often serves for muscular attachment.

Beneath the beak of each valve frequently occurs a flat " cardinal area ", bounded above by the *cardinal slopes* and below by the articulating margin or *hinge line*. This area is commonly divided in the center by a triangular fissure (*delthyrium*). It may be covered either by a single plate (*deltidium*) or by two plates which join in the center (*deltidial plates*).

The important surface features of the shell are: the *lines of growth*, the radiating *plications* or *striations*, the *fold* or medial elevation, and the *sinus* or medial depression, the fold commonly occurring on the brachial, and the sinus on the pedicle valve.

Genus LINGULA Bruguière

[Ety.: *lingula*, little tongue]

(1789. *Hist. nat. des vers testacés;* 1892. *Pal. N. Y.* v. 8, pt 1, p. 2)

Shell with the valves nearly equal and varying in outline from elongate ovate to subtriangular, always longer than wide; valves arched. Animal attached by a long muscular pedicle which protrudes from between the beaks of the two valves.

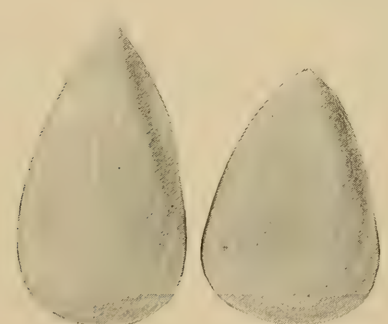


Fig. 81 Lingula cuneata enlarged x 2

Lingula cuneata Conrad (Fig. 81)

(Hall. 1852. *Pal. N. Y.* 2:8, pl. 4)

Distinguishing characters. Acutely cuneate form; very acute beak with nearly rectilinear margins; slightly curved base; valves convex near the beak, flatter toward front; fine longitudinal striae.

Found in the upper Medina sandstones at Niagara. Also at Lockport etc. (Hall).

Genus PHOLIDOPS Hall

[Ety.: φολίς, a scale]

(1859. *Pal. N. Y.* 3:489; 1892. *Pal. N. Y.* v. 8, pt 1, p. 155)

Shells small, with equal valves, patella-like in outline; inarticulate and unattached, without pedicle opening; position of apex variable; edges of valves flattened where they meet, and on the interior are elevated areas for attachment of muscles, etc. In molds of the interior, a strongly marked impression of this callosity appears.

Pholidops squamiformis Hall (Fig. 82). Orbicula ? squamiformis Hall (1852. *Pal. N. Y.* 2:250, pl. 53, fig. 4a-b)

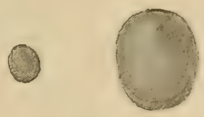


Fig. 82 Pholidops squamiformis natural size and enlarged

Distinguishing characters. Depressed oval form; squamous concentric striae, most marked on anterior slope.

Found near the middle of the lower Rochester shales at Niagara. Also at Lockport (Hall).

Genus DICTYONELLA Hall

[Ety.: δίκτυον, net]

(1867. *N. Y. state cab. nat. hist. 20th an. rep't*, p. 274; 1893. *Pal. N. Y.* v. 8, pt 2, p. 307)

Shell subtriangular in outline with biconvex valves, pedicle valve having a broad median sinus, and brachial valve a corresponding fold; beak of pedicle valve acute and arched over that of brachial valve, though not closely appressed against it; a short, triangular deltidium depressed within the cavity of the pedicle valve; teeth long, marginal and ridge-like on the diverging cardinal slopes and fitting into narrow marginal grooves on the brachial valve; brachial valve with a strong median septum. Exterior covered by a coarse network of superficial cells, usually hexagonal, sometimes circular in outline. A triangular area at the umbo of the pedicle valve is destitute of this reticulation.

Dictyonella corallifera Hall (Fig. 83). Atrypa corallifera Hall (1852. *Pal. N. Y.* 2:281, pl. 58, fig. 5a-t)

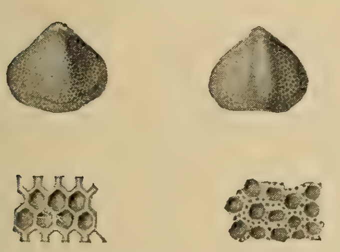


Fig. 83 Dictyonella corallifera with surface enlarged

Distinguishing characters. Form rhomboidal to subtriangular, base often nearly straight; broad and strong sinus and fold; reticulated or pitted surface, the space between the pits often punctate.

Found in the Bryozoa beds of the Rochester shale at Niagara. Also at Lockport (Hall).

Genus LEPTAENA Dalman

[Ety.: λεπτός, thin]

(1828. *Kongl. Svenska Vet. Akad. Handl.* p. 93,94)

Shells concavo-convex; surface covered by conspicuous concentric corrugations or wrinkles over the flatter portions of the valves. Where these cease, the surface is more or less abruptly deflected, forming a conspicuous anterior slope. Whole exterior covered with fine, radiating, tubular striae, which in well preserved specimens are crenulated by finer concentric striae. Hinge line straight; cardinal area narrow. A convex deltidium present, perforated at the apex by a foramen, which often encroaches on the apex of the valve. A trilobed cardinal process and well defined muscular impressions are present.

Fig. 84 Leptaena rhomboidalis

Leptaena rhomboidalis (Wahlenberg) (Fig. 84). Leptaena depressa Hall (1852. *Pal. N. Y.* 2:257, pl. 53, fig. 6a-l)

Distinguishing characters. Corrugated part gently convex to slightly concave; abrupt anterior deflection; strong concentric corrugations and fine striae. Narrow hinge area.

Found in the upper Clinton limestone, the Clinton lenses, and the lower Rochester shale up to and in the Bryozoa bed. Rarely above this. Also at Lockport and elsewhere (Hall).

Genus STROPHEODONTA Hall

[Ety.: στροφή, bend; ὀδούς, tooth]

(1852. *Pal. N. Y.* 2:63. Hall & Clarke, 1892; *Pal. N. Y.* v. 8, pt 1, p. 284)

Shell normally concavo-convex; hinge line usually equal to or greater than the greatest width of the shell. Area of the pedicle valve higher than that of the brachial valve, both furnished with projecting denticulations, which interlock and form articulations. Muscular areas well marked and variously bounded. A strongly marked bifid cardinal process occurs in the brachial valve.

Stropheodonta corrugata (Conrad) (Fig. 85) (Hall. 1852. *Pal. N. Y.* 2:59, pl. 21)

Distinguishing characters. Semioval, nearly flat; small, acute lateral extensions of hinge; fine, prominent striae sometimes bifur-

Fig. 85 Stropheodonta corrugata; with surface enlarged

cating or alternating with finer ones; oblique folds on hinge margin.

Found in the Clinton limestone (?) and the Clinton lenses at Niagara. Rare.

Stropheodonta profunda Hall (Fig. 86) (1852. *Pal. N. Y.* 2:61, pl 21)

Distinguishing characters. Large, semioval, much wider than high; auriculate hinge; profoundly concave brachial valve; abruptly

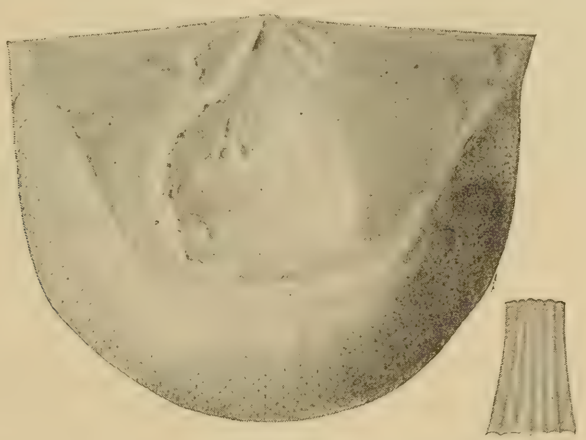


Fig. 86 Stropheodonta profunda with enlargement of striae

deflected margins; fine, unequal surface striae; papillose or punctate interior.

Found in the lower and upper Clinton limestone at Niagara. Also in the latter bed at Lockport (Hall).

Genus STROPHONELLA Hall

[Ety.: στρόφος, turned around]

(1879. *N. Y. state mus. nat. hist., 26th an. rep't*, p. 153; Hall & Clarke. 1892. *Pal. N. Y.* v. 8, pt 1, p. 290)

Shells with the form and structure of Stropheodonta, but with the relative convexity of the valves reversed.

Strophonella striata Hall (Fig. 87) Leptaena striata Hall (1852. *Pal. N. Y.* 2:259, pl. 53, fig. 7)

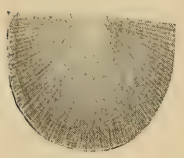


Fig. 87 Strophonella striata

Distinguishing characters. Semielliptic, almost flat, hinge line equal to or a little longer than width of shell; fine, rounded, radiating surface striae, which increase by implantation; fine concentric striae.

Found in the middle and upper Rochester shale at Niagara.

Strophonella (?) patenta Hall (Fig. 88). Leptaena patenta Hall (1852. *Pal. N. Y.* 2:60, pl. 21)

Distinguishing characters. Wider than high; hinge not auriculate; fine unequal radii crossed by finer concentric striae; inner surfaces of valves thickly covered with sharp points.

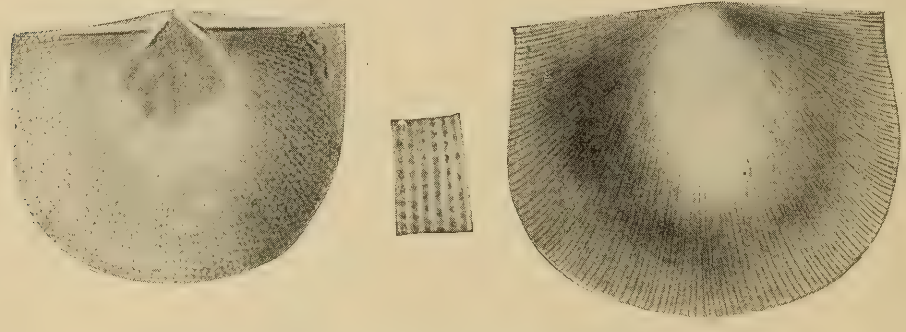


Fig. 88 Strophonella (?) patenta with enlarged surface features

Found in the Clinton limestones and lenses and doubtfully in the middle Rochester shales at Niagara.

Genus PLECTAMBONITES Pander

[Ety.: πλεκτός, plaited; ἄμβων, beak]

(1830. *Beiträge zur Geognosie des Russ. Reiches.* p. 90. Hall & Clarke, 1892; *Pal. N. Y.* v. 8, pt 1, p. 236, 295)

Shells small, concavo-convex; surface striae very fine, often alternating in size; hinge line making greatest width, extremities often

subauriculate; cardinal areas narrow, sometimes obscurely crenulated on the margins. Delthyrium partially closed by convex plate, but mostly occupied by cardinal process of opposite valve. Cardinal process appears trilobate. Muscular areas moderately well defined.

Plectambonites sericea (Sowerby) (Fig. 89). Leptaena sericea Hall (1852. *Pal. N. Y.* 2:59, pl. 21)

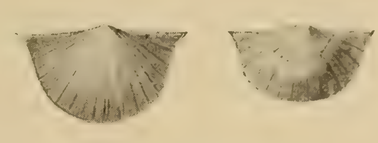


Fig. 89 Plectambonites sericea

Distinguishing characters. Outline semicircular to semioval; hinge line extended, ending in acute points; striae strong, elevated, alternating with finer ones.

Found in the lower Clinton limestone at Niagara. Rare.

Plectambonites transversalis (Wahlenberg) (Fig. 90). Leptaena transversalis Hall (1852. *Pal. N. Y.* 2:256, pl. 53, fig. 5a-b)

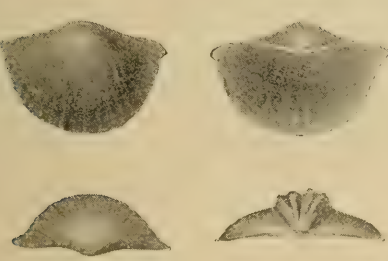


Fig. 90 Plectambonites transversalis

Distinguishing characters. Outline semicircular; strongly convex pedicle, and extremely concave brachial valve, conforming to each other; strongly incurved beak of pedicle valve, which causes an inflection of the hinge line; hinge line produced; fine distant elevated striae with extremely fine striae between; strongly punctate character of exfoliated portions.

Found in the Clinton lenses, and abundantly in the lower Rochester shale at Niagara. Also at Lockport (Hall).

Genus ORTHOTHETES Fischer de Waldheim

[Ety.: ὀρθός, straight]

(1830. *Soc. imp. natural. d. Moscow Bul.* 1:375. Hall & Clarke, 1892; *Pal. N. Y.* v. 8, pt 1, p. 253)

Shell varying from plano-convex to biconvex, sometimes becoming concavo-convex with age. Pedicle valve most convex about the beak, which often tends toward irregular growth; cardinal area well developed, with a thick, more or less convex deltidium. Teeth not supported by dental plates. Brachial valve most convex near

the middle, with a narrow hinge area; cardinal process quadrilobate as seen from above. Surface covered by slender radiating striae, which are crenulated by concentric lines.

Orthothetes subplanus (Conrad) (Fig. 91). Leptaena subplana Hall (1852. *Pal. N. Y.* 2:259, pl. 53, fig. 8-10)

Distinguishing characters. Pedicle valve at first convex, later becoming concave; valves nearly equal in length and width; extended hinge line, sometimes projecting into points; sharp angular or subangular to rounded striae, sometimes bifurcating before reaching

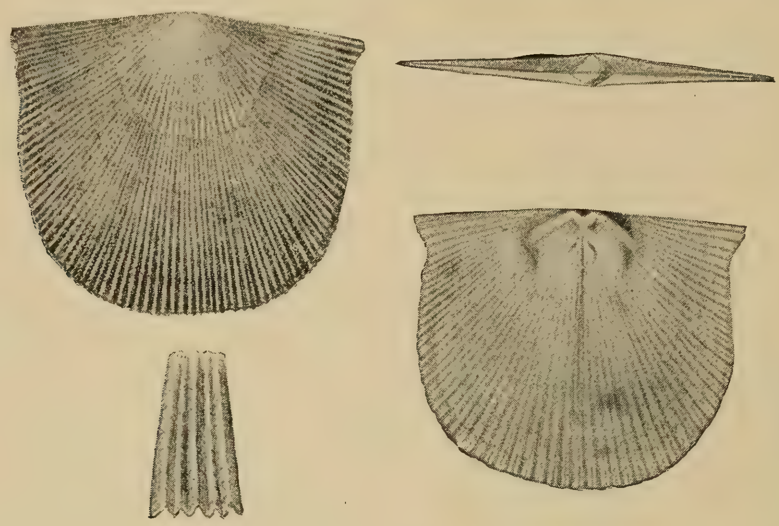


Fig. 91 Orthothetes subplanus

margin, separated by wider interspaces; the usual method of increase is by intercalation of fine striae, which soon grow to strength of the chief ones; fine concentric and occasionally coarser lines of growth.

Found at Niagara in the upper Clinton beds and the Clinton lenses; also abundantly in certain thin calcareous layers of the lower Rochester shale, less common in the middle and upper shale. Also at Lockport and elsewhere (Hall).

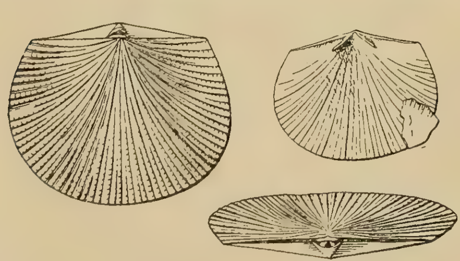


Fig. 92 Orthothetes hydraulicus

Orthothetes hydraulicus (Whitfield) (Fig. 92) (Grabau. *Geol. soc. Am. Bul.* 11:365, pl. 22)

Distinguishing characters. Small size; obtuse cardinal margins with hinge line shorter than greatest width of shell; uniformly rounded front; strong rounded, sharply de-

fined radiating striae, which curve slightly upward on the lateral margins near the cardinal area; strongest striae reaching to beak; increase by repeated intercalation; fine concentric striae.

Found in great abundance in the Manlius limestone of North Buffalo, etc., usually in the condition of molds.

Genus CHONETES Fischer de Waldheim

[Ety.: χώνη, funnel]

(1837. *Oryctographie du gouv. de Moscow,* pt 2, p. 134; 1892. *Pal. N. Y.* v. 8, pt 1, p. 303)

Shells concavo-convex (in our species), with the pedicle valve convex; hinge line straight, making the greatest diameter of the shell; areas narrow; the triangular opening (delthyrium) in the area of the pedicle valve covered by a convex deltidium. Upper margin of area bears a single row of hollow spines. Area of brachial valve without spines; cardinal process appearing quadrilobate. Interior of shell strongly papillose in the pallial region. A low median ridge divides the muscular area of the pedicle valve. A similar ridge occurs in the brachial valve. External surface usually covered by radiating striae.

Chonetes cornutus (Hall) (Fig. 93) (1852. *Pal. N. Y.* 2:64, pl. 21)

Distinguishing characters. Semicircular; fine equal striae, round, straight and bifurcating with similar interspaces; three cardinal spines on each side of beak, obliquely diverging below, curving inward at middle and upper parts; outer one longest.

Fig. 93 Chonetes cornutus natural size and enlarged

Found (doubtfully) in the Lockport limestone at Niagara.

Genus ORTHIS Dalman

(*sensu strictu*)

[Ety.: ὀρθός, straight; in allusion to hinge line]

(1828. *Kongl. Svenska Vet. Akad. Handl.* p. 93, 96. Hall & Clarke 1892; *Pal. N. Y.* v. 8, pt 1, p. 192)

Shells plano-convex in contour; costae strong, sharp and comparatively few, rarely if ever bifurcating; cardinal area of pedicle

valve elevated and somewhat incurved; dental lamellae slightly developed, not extending the entire length of the umbonal cavity. Cardinal process an elongate vertical plate, logitudinally dividing the deep deltidial cavity.

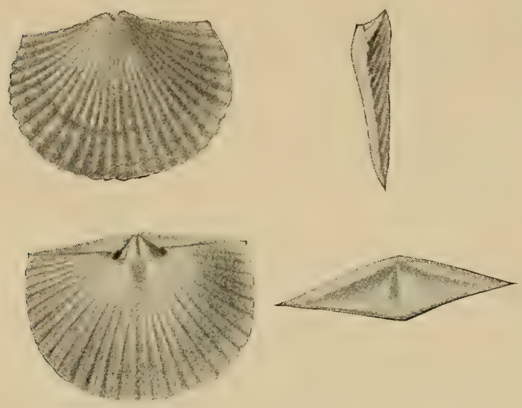


Fig. 94 Orthis flabellites

Orthis flabellites Foerste (Fig. 94). Orthis flabellulum var. Hall (1852. *Pal. N. Y.* 2:254, pl. 52)

Distinguishing characters. Long hinge line; semioval form; coarse, simple rounded plications, equal to spaces between them; marked concentric growth lines.

Found in the upper Clinton limestone and the lower Rochester shale at Niagara. Rare. Also in the shale at Lockport (Hall).

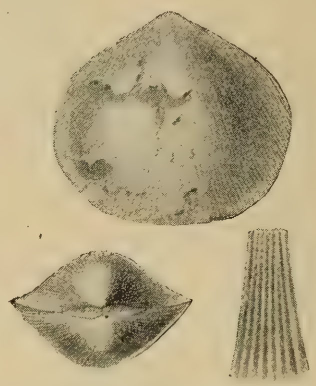


Fig. 95 Orthis (?) punctostriata with enlargement of surface

Orthis (?) punctostriata Hall (Fig. 95) (1852. *Pal. N. Y.* 2:254, pl. 52, fig. 5a-f)

Distinguishing characters. Subglobose contour, nearly equal, extremely convex valves; beak of pedicle valve somewhat longer than that of brachial valve, but both prominent; short hinge line, still shorter but high area; fine equal bifurcating striae; extremely fine concentric striae; punctate interspaces.

Found in the talus of Rochester shale above Lewiston hights. Rare. Also in the shale at Lockport (Hall).

Genus ORTHOSTROPHIA Hall

[Ety.: the name refers to the relations of the genus to Orthis and Stropheodonta]

(1883. *N. Y. state geol. 2d an. rep't,* pl. 36; 1892. *Pal. N. Y.* v. 8, pt 1, p. 199, 223, 253)

Shells with convexity of valves reversed; surface finely plicated; deep narrow muscular area; cardinal process elongate and simple.

Orthostrophia (?) fasciata Hall (Fig. 96). O r t h i s f a s c i a t a Hall (1852. *Pal. N. Y.* 2:255, pl. 52)

Distinguishing characters. Semi-oval contour; produced hinge line; clustered or fasciculated striae almost simple at their origin, dividing toward the margin.

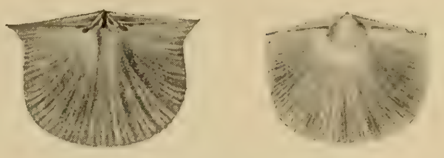


Fig. 96 Orthostrophia (?) fasciata

Found in the lower Rochester shale at Niagara (?). Also at Lockport (Hall).

Genus DALMANELLA Hall & Clarke

[Ety.: proper name]

(1892. *Pal. N. Y.* v. 8, pt 1, p. 205, 223)

Shells plano-convex or subequally biconvex; pedicle valve usually the deeper, often elevated at the umbo and arched over the cardinal area; hinge line generally shorter than the greatest width of the shell; surface finely striate. Prominent teeth supported by lamellae which circumscribe the muscular area; cardinal process tri- to quadrilobed, continued downward in a median ridge dividing a quadriplicate muscular area.

Dalmanella elegantula (Dalman) (Fig. 97). O r t h i s e l e g a n t u l a Dalman (Hall 1852. *Pal. N. Y.* 2:252, pl. 52, fig. 3a-r)

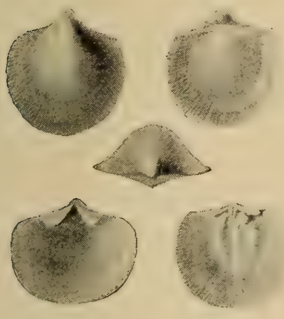


Fig. 97 Dalmanella elegantula

Distinguishing characters. Strongly convex pedicle valve with high but narrow area and incurved beak; nearly flat brachial valve; generally with a longitudinal concavity in the center; fine close set striae, which divide dichotomously toward the margin; extremely fine concentric lines and coarser growth lines.

Found in the Clinton lenses, and abundantly at intervals in the lower and middle (Bryozoa beds) Rochester shales at Niagara. Also at Lockport and elsewhere (Hall).

Genus RHIPIDOMELLA Oehlert

[Ety.: ῥιπίς, fan]

(1891. *Journal de conchyliologie.*, p. 372; 1892. *Pal. N. Y.* v. 8, pt 1, p. 209)

Shell almost circular in outline; both valves gently convex; hinge area short; slight median depression in each valve. Surface covered with fine, rounded, hollow, tubular striae, which frequently open on the surface. On the interior of the pedicle valve are two strong diverging teeth. Muscular area large, and deeply impressed, consisting of fluted diductor impressions, inclosing small central adductors. The pedicle scar fills the cavity of the beak. The interior of the brachial valve shows deep and narrow dental sockets, with prominent projecting crural plates. In the center is a strong cardinal process, below which is the indistinct small muscular area.

Rhipidomella hybrida (Sowerby) (Fig. 98). Orthis hybrida Sowerby (Hall. 1852. *Pal. N. Y.* 2:253, pl. 52)

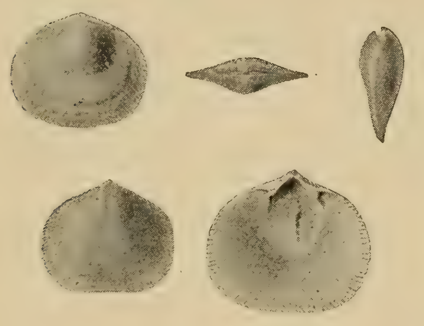


Fig. 98 Rhipidomella hybrida

Distinguishing characters. Wider than long; nearly equal valves; pedicle valve with broad, undefined depression down the center; brachial valve uniformly convex, sometimes slightly depressed near front; beaks nearly equally elevated and scarcely incurved; short hinge area; fine bifurcating striae.

Found in the upper part of the lower Rochester shales and in the Bryozoa bed as well as rarely in the upper shales. Niagara sections. Also at Lockport and elsewhere (Hall).

Rhipidomella circulus Hall (Fig. 99). Orthis circulus Hall (1852. *Pal. N. Y.* 2:56, pl. 20)

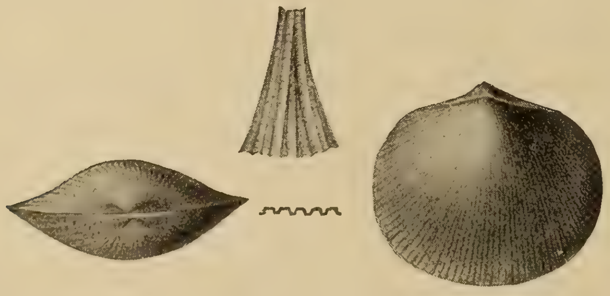


Fig. 99 Rhipidomella circulus with enlargement of surface

Distinguishing characters. Nearly circular and equivalve; finely striated surface; dichotomous striae running upward and outward on the hinge line; narrow short hinge area; slightly sinuous front.

Found in the lower Clinton limestone (?). Also east of Lockport (Hall).

Genus SCENIDIUM Hall

[Ety.: σκηνίδιον, little tent]

(1860. *N. Y. state cab. nat. hist. 13th rep't,* p. 70; 1892. *Pal. N. Y.* v. 8, pt 1, p. 241)

Shells subpyramidal, somewhat semicircular; with or without median sinus or elevation; pedicle valve elevated, subpyramidal; beak straight or slightly arched; cardinal area large, triangular, divided by a narrow fissure, sometimes closed at the summit by a concave plate. Brachial valve depressed convex to concave; cardinal line usually equal to width of shell; cardinal process simple or divided, and extending as a median septum through the length of the shell. Spondylium in the pedicle valve.

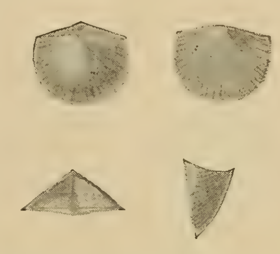


Fig. 100 Scenidium pyramidale enlarged

Scenidium pyramidale Hall (Fig. 100). Orthis pyramidale Hall (1852. *Pal. N. Y.* 2:251, pl. 52, fig. 2a-z)

Distinguishing characters. Minute, subpyramidal; flat semicircular brachial valve, centrally depressed; extremely elevated pedicle valve with large triangular area; strong radiating striae, sometimes dichotomous; lamellose concentric striae.

Found in the Rochester shale at Lockport (Hall) and may also occur at Niagara.

Genus ANASTROPHIA Hall

[Ety.: ἀνά, back; στροφή, a turning]

(1867. *N. Y. state cab. nat. hist. 20th an. rep't,* p. 163; 1893. *Pal. N. Y.* v. 8, pt 2, p. 224)

Pentameroid shells with a spoon-shaped cavity (spondylium) under the beak of the pedicle valve and with a moderate cardinal line but no hinge area; surface with numerous sharp plications extending to the beak.

Anastrophia interplicata (Hall) (Fig. 101). Atrypa interplicata Hall (1852. *Pal. N. Y.* 2:275, pl. 57)

Fig. 101 Anastrophia interplicata

Distinguishing characters. Extremely convex; brachial valve the deepest; moderate sinus and fold; from two to three plications in the former and three to four on the latter; lateral plications increase by implantation.

Found in the Clinton lenses, and in the lower and middle Rochester shale at Niagara. Also in the shale at Lockport (Hall).

Anastrophia brevirostris Hall (Fig. 102) Atrypa brevirostris Hall (1852. *Pal. N. Y.* 2:278, pl. 58)

Fig. 102 Anastrophia brevirostris

Distinguishing characters. Wider than high; strongly convex; brachial valve deepest; short nearly equal beaks; sharp bifurcating or interpolated plications, from five to six in the sinus and fold, which are broad and ill defined.

Found in the lower Rochester shale at Niagara (?). Also in the shale at Lockport (Hall).

Genus PENTAMERUS Sowerby

[Ety.: πέντε, five; μέρος, part]

(1813. Sowerby. *Mineral conchology,* 1:76; Hall & Clarke. 1893. *Pal. N. Y.* v. 8, pt 2, p. 236)

Shell strongly inequivalve, biconvex with highly arched pedicle valve; surface smooth, or with a few broad and obscure radiating undulations. Under the beak of the pedicle valve is a deep and narrow *spondylium,* or plate with an excavated spoon-shaped cavity, supported by a high vertical septum of variable length; brachial valve with a pair of septa, the interior of the shell being thus divided into five compartments.

Pentamerus oblongus Sowerby (Fig. 103) (Hall. 1852. *Pal. N. Y.* 2:79, pl. 25)

Distinguishing characters. Very large and oblong, varying in outline with age; wider in anterior part; valves strongly convex at beaks; beak of pedicle valve overarching; subtrilobate division of

valves in some specimens; surface marked only by concentric lines of growth, which are strongest in old shells.

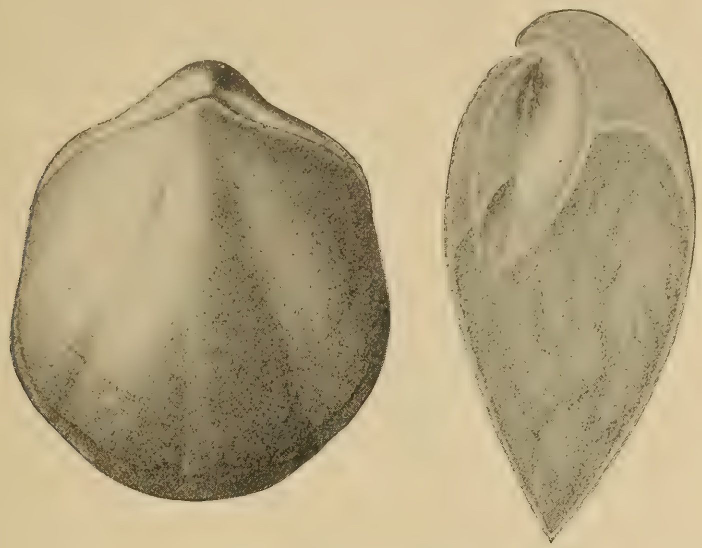


Fig. 103 Pentamerus oblongus

Found in the upper crystalline Clinton limestone at Niagara (1 specimen). The species is characteristic of the lower Clinton limestone, east of Lockport.

Genus BARRANDELLA Hall & Clarke

[Ety.: proper name]

(Hall & Clarke. 1894. *Pal. N. Y.* v. 8, pt 2, p. 241, 243)

Small pentameroid shells, of a galeate form or helmet-shaped contour, with a smooth, or rarely plicated surface. A spondylium is present, but is not supported by a septum.

Barrandella fornicata (Hall) (Fig. 104). Pentamerus fornicatus Hall (*Pal. N. Y.* 2:81, pl. 24)

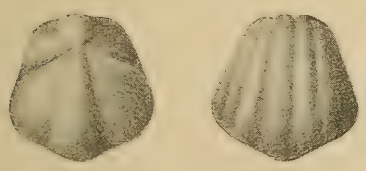


Fig. 104 Barrandella fornicata

Distinguishing characters. Helmet-shaped contour, very convex pedicle valve, with overarching beak; surface obscurely plicate longitudinally.

Found in the upper crystalline Clinton limestone at Niagara. Also in the same limestone at Lockport (Hall).

Genus RHYNCHOTRETA Hall

[Ety.: ῥύγχος, beak; τρητά, with a hole]

(1879. *N. Y. state mus. nat. hist. 28th an. rep't*, p. 166; 1893. *Pal. N. Y.* v. 8, pt 2, p. 185)

Shell triangular; surface with angular plications. Beak of pedicle valve straight, produced beyond that of the opposite valve, extremity perforate, the foramen with an elevated margin. Two longitudinally striated deltidial plates fill the delthyrium. Teeth slender, curving, proceeding from a broad curving hinge plate in the pedicle valve. Brachidium a slightly modified loop.

Rhynchotreta cuneata var. **americana** Hall (Fig. 105). Atrypa cuneata Hall (1852. *Pal. N. Y.* 2:276, pl. 57, fig. 4a-r)

Fig. 105 Rhynchotreta cuneata var. americana

Distinguishing characters. Triangular and cuneiform outline; longer than wide; elongate angular beak of pedicle valve with compressed, flat or concave sides; wide, deep sinus in adult, extending two thirds to the beak; profound frontal emargination; strong angular plications, three in sinus, four on fold, the two central ones most prominent; numerous regular, fine thread-like concentric striae; minutely papillose surface.

Found in the Clinton lenses and the lower Rochester shale and particularly in the Bryozoa beds, where it is abundant; rarely above this. Niagara sections. Also at Lockport and elsewhere (Hall).

Genus CAMAROTOECHIA Hall & Clarke

[Ety.: καμάρα, arched chamber; τοῖχος, partition]

(1893. *Pal. N. Y.* v. 8, pt 2, p. 189)

Shell rhynchonelloid, trihedral in contour, with shallow pedicle and convex brachial valve; no hinge area; beak of pedicle valve projecting and incurved. Surface radially plicate, sinus and fold in pedicle and brachial valves respectively. Distinctive internal characters (separating this genus from other "Rhynchonellas") are: a

median septum in the brachial valve, which divides posteriorly, so far as to form an elongate cavity, which does not extend to the bottom of the valve. No cardinal process. In the pedicle valve slender vertical lamellae support the teeth.

Camarotoechia obtusiplicata Hall (Fig. 106). Atrypa obtusiplicata Hall (1852. *Pal. N. Y.* 2:279, pl. 58, fig. 2a-h)

Distinguishing characters. Gibbous, subspheroidal form; strongly convex brachial, and flatter pedicle valve; deep sinus of pedicle

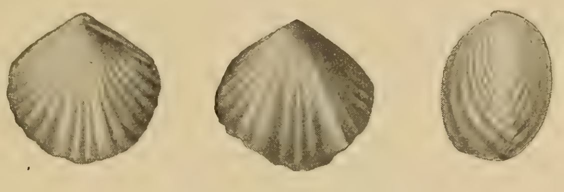


Fig. 106 Camarotoechia obtusiplicata

valve with three plications (rarely four); depressed incurved beak of pedicle valve; simple, obtusely rounded or flattened plications; faint concentric striae; strongly emarginate front.

Found in the lower part of the lower Rochester shales at Niagara. Also in the shales and limestones at Lockport (Hall).

Camarotoechia (?) neglecta Hall (Fig. 107). Atrypa neglecta Hall (1852. *Pal. N. Y.* 2:70, 274, pl. 23 and 57)

Distinguishing characters. Convex valves, brachial valve deepest, sides sloping abruptly to the beak; strongly defined sinus and fold, in adult individual, the former with three, the latter with four plications; profound frontal emargination; plications rounded.

Fig. 107 Camarotoechia (?) neglecta

Found in the lower Clinton limestone in the Clinton lenses and in the upper part of the lower and the middle Rochester shales at Niagara. Also more rarely in the upper shales. Found also at Lockport and elsewhere (Hall).

Camarotoechia acinus Hall (Fig. 108). Rhynchonella acinus Hall (*N. Y. state mus. nat. hist. 28th an. rep't,* p. 163, pl. 26)

Distinguishing characters. Small size; longitudinally ovate form, narrowing toward beak, truncate in front; subequally convex valves;

a single plication in sinus of pedicle valve and two on fold of brachial valve; few plications on either side of fold or sinus.

Fig. 108 Camarotoechia acinus. A specimen in which the fold and sinus are not developed. Enlarged x 4

Found in the crystalline upper Clinton limestone at Niagara. The species was originally described from the western Niagara.

Genus RHYNCHONELLA Fischer de Waldheim

[Ety.: ῥύγχος, beak]

(1809. *Notice des fos. gouv. Moscow.* p. 35; Hall & Clarke. 1893. *Pal. N. Y.* v. 8, pt 2, p. 177, 178)

Subpyramidal plicated shells with a prominent anterior linguiform extension. Dental lamellae and a dorsal median septum occur, but no cardinal process; crura are present, but other arm supports are wanting.

Fig. 109 Rhynchonella robusta

Rhynchonella robusta Hall (Fig. 109). Atrypa robusta Hall (1852. *Pal. N. Y.* 2:71, pl. 23)

Distinguishing characters. Large size; robust character; brachial valve most convex; broad, ill defined fold and sinus; coarse rounded plications.

Found in the uppermost beds of the Clinton series at Niagara. Also east of Lockport (Hall).

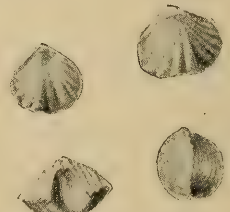


Fig. 110 Rhynchonella (?) bidens

Rhynchonella (?) bidens Hall (Fig. 110). Atrypa bidens Hall (1852. *Pal. N. Y.* 2:69, pl. 23)

Distinguishing characters. Much smaller than preceding; strong convexity of valves; deep sinus with one plication; fold consisting of two rounded plications; rather broad, rounded lateral plicae; strongly emarginate front.

Found in the lower Clinton beds at Lockport (Hall). Probably also at Niagara.

Rhynchonella (?) bidentata (Hisinger) (Fig. 111). Atrypa bidentata Hall (1852. *Pal. N. Y.* 2:276, pl. 57)

Fig. 111 Rhynchonella (?) bidentata with surface enlarged

Distinguishing characters. Triangular form; acute, extended beak of pedicle valve; stronger convexity of brachial valve; less convex and more triangularly acute than preceding; very slight frontal emargination; shallow sinus with one plication, and corresponding fold with two.

Found in the Rochester shale at Lockport and elsewhere (Hall). Probably also at Niagara.

Genus ATRYPA Dalman

[Ety.: α, without; $\tau\rho\tilde{\upsilon}\pi\alpha$, foramen (erroneous)]

(1828. *Kongl. Vetenskaps Akad. Handlingar*, p. 127; 1894. *Pal. N. Y.* v. 8, pt 2, p. 163)

Shell varying in outline from nearly circular to longitudinally suboval; valves very unequal, brachial valve being strongly convex or gibbous, while the pedicle valve is gently convex or almost flat or sometimes slightly concave from the strongly marked sinus; beak of the pedicle valve small and incurved over that of the brachial. Large widely separated and doubly grooved teeth are present, unsupported by lamellae. Strong muscular impressions. Spirals of the brachidium with their bases parallel to the inner surface of the pedicle valve, and the apexes directed toward the deepest point of the opposite valve. Surface radially plicate.

Atrypa reticularis (Linnaeus) (Fig. 112) (1852. *Pal. N. Y.* 2:272, pl. 23, p. 270, pl. 55)

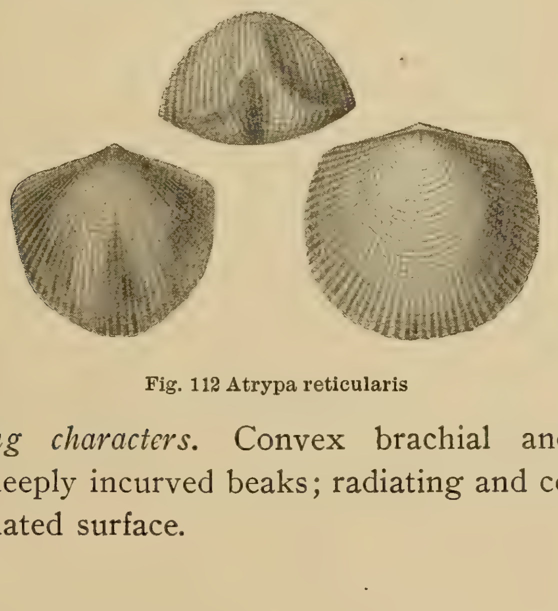


Fig. 112 Atrypa reticularis

Distinguishing characters. Convex brachial and flat pedicle valves; small deeply incurved beaks; radiating and concentric striae forming reticulated surface.

Found in all the beds from the upper Clinton limestones to the Bryozoa beds. Most abundant in the Clinton.

In the light colored crystalline upper Clinton limestone this species is very abundant, but also very variable. Strong robust and very rotund specimens occur, with brachial valve excessively bulging, and with narrow simple rounded striae, increasing by implantation, and cancelated by concentric striae of moderate strength, and stronger undulations on the mature portions. Other specimens, less rotund and with bifurcating striae occur. When bifurcation of striae occurs, this is usually found on the pedicle valve, those of the brachial valve increasing only by intercalation. The pedicle valve usually has a sinus near the front, and the striae and concentric lines increase in strength, approaching the characters of the next species. In the Clinton lenses this character becomes still more pronounced, the shells at the same time decreasing in size and rotundity. In the Rochester shales the species is generally much less abundant, A. nodostriata being the prominent form. A. reticularis is represented by small and generally flattened specimens, in which the radiating striae are usually fine, and the concentric striae lamellose, specially in the adult portions. Increase of striae occurs by both intercalation and bifurcation, the former on the brachial, the latter on the pedicle valve. In some specimens the bifurcation occurs close to the beak.

Fig. 113 Atrypa nodostriata, with striae enlarged

Atrypa nodostriata Hall (Fig. 113) (1852. *Pal. N. Y.* 2:272, pl. 56)

Distinguishing characters. Subequal valves, nearly equally convex in young, pedicle valve more convex with age; small slightly elevated beak of pedicle valve; mesial sinus in adult shells, broad and undefined; strong rounded bifurcating plications; lamellose growth lines which give nodulose appearance to surface.

Found in the Clinton lenses, and the lower and middle Rochester shale at Niagara. Specially abundant in the Bryozoa beds. Also found at Lockport and elsewhere (Hall).

Atrypa rugosa Hall (Fig. 114) (1852. *Pal. N. Y.* 2:271, pl. 56)

Distinguishing characters. Generally smaller than preceding; equally convex valves in adult, unequal in young, the brachial valve

being almost flat. Strong sinus and fold in adult, with minor plications on each; strong concentric rugose lamellae; plications less rounded than preceding.

Found in the Clinton and Rochester beds at Niagara, generally associated with the preceding but much less common. Also at Lockport, etc. (Hall).

Fig. 114 Atrypa rugosa with striae enlarged

Genus CYRTINA Davidson

[Ety.: κυρτία, a wicker shield]

(1858. *British Carbon. Brachiopoda.* Monograph, p. 66; 1893. *Pal. N. Y.* v. 8, pt 2, p. 43)

Shells Spirifer-like; usually small; valves very unequal; pedicle valve elevated, with a high cardinal area, the delthyrium of which is covered by an elongate, convex pseudodeltidium, which is perforated below the apex; surface plicate. Dental lamellae strong, converging rapidly, and meeting a median septum. Cardinal process a double apophysis. Brachidium an extroverted spire.

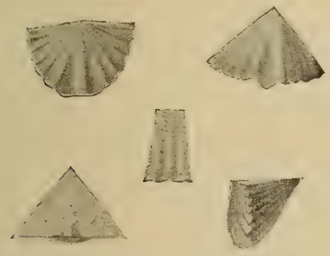


Fig. 115 Cyrtina pyramidalis with striae enlarged

Cyrtina pyramidalis (Hall) (Fig. 115). Spirifer pyramidalis Hall (1852. *Pal. N. Y.* 2:266, pl. 54)

Distinguishing characters. Pyramidal form; vertical or slightly bent area; nearly flat brachial valve; extremely convex pedicle valve; subangular plications, about five on each side of mesial fold and sinus.

Found "near the top and just below the edge of the cliff on the Niagara river above Lewiston" (Hall).

Genus SPIRIFER Sowerby

[Ety.: *spira*, spire; *fero*, to bear]

(1815. *Mineral conchology*, 2:42; 1894. Hall & Clarke. *Pal. N. Y.* v. 8, pt 2, p. 1)

Shell variously shaped, commonly very much wider than long, radially plicated or striated, crossed by concentric growth lines, which in some forms are lamellose or even marked by spines.

Hinge line generally long and straight; pedicle valve usually with moderately high area, with an open delthyrium, the margins of which are prolonged into stout simple teeth, supported by dental lamellae. Area of the brachial valve the lower. A calcareous brachidium in the form of a double spire, whose apexes are directed toward the cardinal angles, nearly fills the cavity of the shell.

Spirifer radiatus Sowerby (Fig. 116) (Hall. 1852. *Pal. N. Y.* 2:66, pl. 22, p. 265, pl. 54)

Distinguishing characters. Moderately large size; pedicle valve with strongly incurved beak, moderate area, and broad shallow

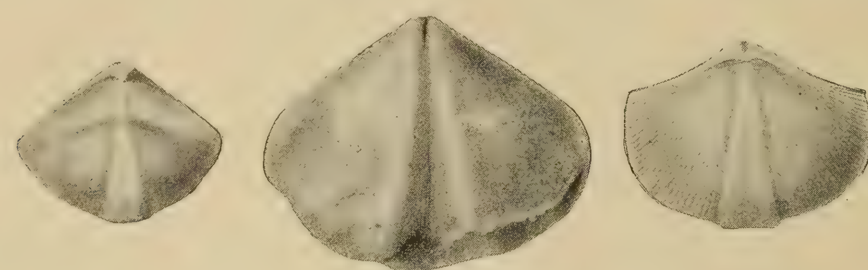


Fig. 116 Spirifer radiatus showing variation

mesial sinus; flattened median fold; fine uniform radiating striae covering all parts of the shell.

Found in the Clinton limestones and lenses and in the lower and middle Rochester shales at Niagara; sometimes abundant. Also at Lockport and elsewhere (Hall).

The shell varies greatly in form and proportions; sometimes the hinge area is much extended or the hinge extremities are rounded and the hinge line shorter than the shell below. Faint plications near the fold and sinus also occur in some specimens, connecting this species with the next.

Spirifer niagarensis Conrad (Fig. 117) (Hall. 1852. *Pal. N. Y.* 2:264, pl. 54)

Fig. 117 Spirifer niagarensis

Distinguishing characters. Moderately large size; convex, with nearly equal valves; strongly incurved beak of pedicle valve; moderate area; numerous fine, rounded, depressed plications, which become obsolete toward the extremities, and sometimes appear quite flattened out on the surface; fine thread-like radiating striae covering plications and interspaces alike.

Found in the upper Clinton limestone and the Clinton lenses and abundantly throughout the lower and middle Rochester shale at Niagara. Also at Lockport and elsewhere (Hall).

Spirifer crispus (Hisinger) (Fig. 118) (Hall. 1852. *Pal. N. Y.* 2:262, pl. 54)

Distinguishing characters. Small size; very convex pedicle valve with incurved beak and high area, which does not extend to car-

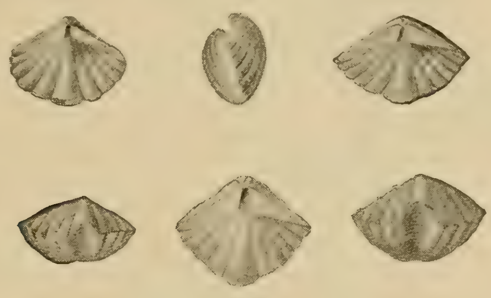


Fig. 118 Spirifer crispus

dinal extremities; broad rounded plications, from six to eight on each valve, strongest near the fold and sinus; fine, elevated, thread-like concentric striae.

Found in the Clinton lenses and the lower and particularly the middle Rochester shale (Bryozoa beds) at Niagara. Also at Lockport and elsewhere (Hall).

Spirifer crispus var **corallinensis** Grabau. (*Geol. soc. Am. Bul.* 11:352; Hall. 1852. *Pal. N. Y.* 2:328, pl. 74, fig. 9a-h)

Distinguishing characters. Uniformly obsolescent plications, angular mesial sinus; otherwise like preceding.

Found in the Clinton lower limestone, the lenses, and the lower Rochester shale. Not abundant. This variety connects S. crispus with S. eriensis. It is characteristic of the Coralline limestone of eastern New York.

Spirifer eriensis Grabau (Fig. 119) (*Geol. soc. Am. Bul.* 2:366, pl. 21)

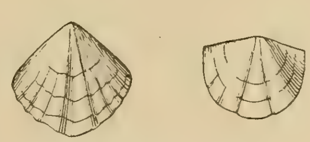


Fig. 119 Spirifer eriensis

Distinguishing characters. Ventricose pedicle valve, of subrhomboidal outline, high area, pronounced angular mesial sinus uniformly increasing in width forward, strong frontal emargination; sinus bounded by strong rounded prominent plications, with fainter

ones on either side; linear interspaces; sharply defined fold of brachial valve, with plications almost obsolete.

Found only in the Manlius limestone of North Buffalo and Williamsville. Not common.

Spirifer (Delthyris) sulcatus Hall (Fig. 120) (1852. *Pal. N. Y.* 2:261, pl. 54)

Fig. 120 Spirifer (Delthyris) sulcatus with striae enlarged

Distinguishing characters. Nearly equal valves; deep mesial sinus; four or more plications on either side, with wide interspaces; fine radiating striae crossing plications and interspaces; very coarse, lamellose, subequally spaced concentric growth lines which interrupt the radiating striae.

Found rarely in the Clinton lenses and the lower Rochester shale; more common in the Bryozoa beds at Niagara. Also at Lockport and elsewhere (Hall).

Genus HOMOEOSPIRA Hall & Clarke

[Ety.: ὅμοιος, like; σπεῖρα, spire]

(1893. *Pal. N. Y.* v. 8, pt 2, p. 112)

Shell rostrate, radially plicate, and with a short curved hinge line; apex truncated by a circular pedicle opening. Spirals spiriferoid, with from six to nine volutions and a V-shaped jugum. A linear cardinal process separates the crural plates.

Homoeospira apriniformis Hall (Fig. 121). Atrypa aprinis Hall (1852. *Pal. N. Y.* 2:280, pl. 57)

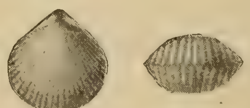


Fig. 121 Homoeospira apriniformis

Distinguishing characters. Small, roundish, oval, scarcely longer than wide; nearly equally convex valves; nonsinuate front, numerous simple rounded plications; fine concentric striae.

Found in the Rochester shale at Lockport (Hall). Probably also at Niagara.

Genus TREMATOSPIRA Hall

[Ety.: τρῆμα, foramen; σπεῖρα, spire]

(1859. *N. Y. state mus. nat. hist. 12th an. rep't*, p. 27; 1893. *Pal. N. Y.* v. 8, pt 2, p. 124)

Shells transverse, with subequally convex valves; surface radially plicate; hinge line straight, cardinal extremities abruptly rounded; anterior margin sinuate. Pedicle valve with a median sinus and an incurved beak, truncated by a circular foramen. Delthyrium covered by two short incurved plates, which are usually closely ankylosed, and appear continuous, with a narrow, flattened area on either side; lower half of the delthyrium open, for the reception of the beak of the brachial valve. Teeth prominent, arising from the bottom of the valve; above the hinge line they curve backward and toward each other, thus making a very firm articulation. Muscular area well defined. Brachial valve with median fold, and minute beak. Hinge plate greatly elevated, with a small chilidium resting against it; upper face of plate deeply divided by median longitudinal groove, and more faintly by transverse groove. Dental sockets small and deep, crura broad, thin and comparatively short. Brachidium of two spiral cones set base to base, as in Spirifer.

Trematospira camura Hall (Fig. 122). Atrypa camura Hall (1852. *Pal. N. Y.* 2:273, pl. 56)

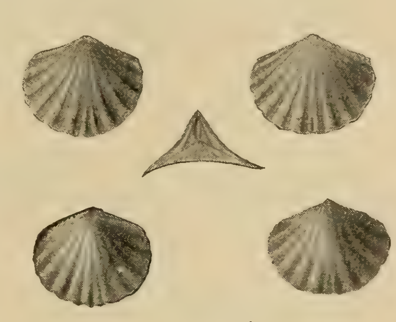


Fig. 122 Trematospira camura

Distinguishing characters. Small; subrhomboidal to transversely elongate; nearly equally convex valves. Small, acute, projecting and slightly incurved beak of pedicle valve, showing in young shells the ankylosed deltidial plates; strong, distant, simple subangular plications, one or two fine ones in the center; fine, thread-like concentric striae and coarse lamellae.

Found in the Bryozoa beds of the Rochester shale at Niagara, rather common. Also at Lockport and elsewhere (Hall).

Genus WHITFIELDELLA Hall & Clarke

[Ety.: proper name]

(1893. *Pal. N. Y.* v. 8, pt 2, p. 58)

Shells usually of small size; valves subequally convex, ovate or elongate in outline; beak of pedicle valve not high or greatly in-

curved, usually exposing the circular apical foramen, beneath which the deltidial plates are frequently retained. Cardinal slopes of both valves broad and not distinctly defined; anterior margin subtruncate and gently sinuate. Hinge plate in brachial valve concave, divided by a deep central concavity, which is supported by a medium septum. Brachidium consisting of two spiral cones arranged base to base, connected by a V-shaped jugum.

Whitfieldella nitida Hall (Fig. 123). Atrypa nitida Hall (1852. *Pal. N. Y.* 2:268, pl. 55)

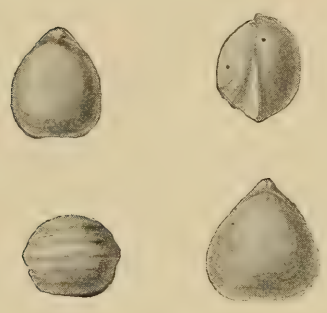


Fig. 123 Whitfieldella nitida

Distinguishing characters. Small size; strong convexity of valves, which are nearly equal, pointed incurved beak of pedicle valve; smooth surface except for concentric growth lines and strong wrinkles of growth; often slight sinus near the front of both valves, causing slight frontal emargination.

Found abundantly in the Clinton lenses and less commonly in the Rochester shale at Niagara.

This species varies from broadly to narrowly ovate; the thickness is frequently greater than the width and coarse thickenings and wrinkles show changes in growth. This may characterize senile individuals.

Whitfieldella nitida var. oblata Hall (Fig. 124). Atrypa nitida var. oblata Hall (1852. *Pal. N. Y.* 2:269, pl. 55)

Distinguishing characters. Broadly ovate form, angle between cardinal slopes often 90° or more; moderately convex valves, subtriangular in cross-section; uniformly rounded front; surface absolutely smooth, very deep muscular impressions.

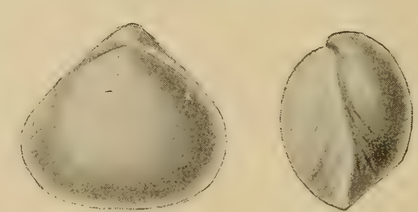


Fig. 124 Whitfieldella nitida var. oblata

Found in the Clinton lenses and the Rochester shale associated with the preceding and usually more abundant. Also at Lockport, etc. (Hall).

Whitfieldella oblata Hall (Fig. 125). A t r y p a o b l a t a Hall (1852. *Pal. N. Y.* 2:9, pl. 4)

Distinguishing characters. Oblate form, nearly as broad as high; broadest anteriorly; sloping abruptly to the beak; small, well

Fig. 125 Whitfieldella oblata

defined beak; nearly equally convex valves; central groove on pedicle valve and slight elevation on brachial valve; surface marked only by lines of growth.

Found in the upper Medina sandstone at Niagara. Also at Lockport (Hall).

Whitfieldella intermedia Hall (Fig. 126). A t r y p a i n t e r m e d i a Hall (1852. *Pal. N. Y.* 2:77, pl. 24)

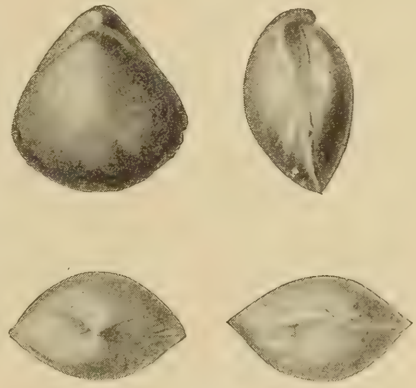


Fig. 126 Whitfieldella intermedia

Distinguishing characters. Obovate; rapidly expanding to front, which is abruptly rounded; length and width nearly equal; convex near beak, flatter toward front; slight frontal sinuosity; faint growth lines.

Found in the Clinton lenses and lowest Clinton shales at Niagara. Also in the upper Clinton limestone at Lockport (Hall).

Whitfieldella cylindrica Hall (Fig. 127). A t r y p a c y l i n d r i c a Hall (1852. *Pal. N. Y.* 2:76, pl. 24)

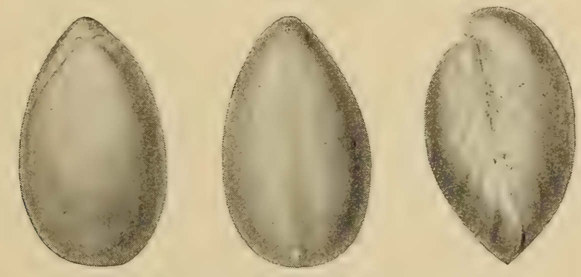


Fig. 127 Whitfieldella cylindrica

Distinguishing characters. Elongate cylindric; strongly convex; nearly as wide as thick; strongly overarching beak of pedicle valve;

faint mesial depression in pedicle valve; slight frontal sinuosity; fine radiating striae near the front.

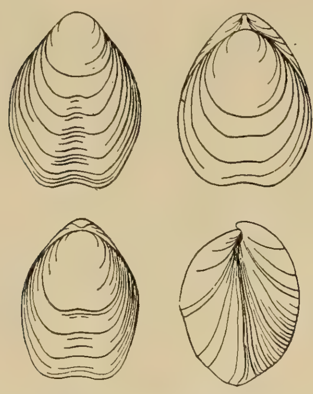


Fig. 128 Whitfieldella sulcata x 1½

Found in the upper Clinton limestone at Lockport (Hall). Probably also at Niagara.

Whitfieldella sulcata (Vanuxem) (Fig. 128) (Grabau. *Geol. soc. Am. Bul.* 11:367, pl. 22)

Distinguishing characters. Ventricose, elongate; well marked sinus in both valves; lines of growth and prominent wrinkles and changes in direction of growth.

Found in the Manlius limestone of North Buffalo, etc.

Whitfieldella rotundata (Whitfield) (Fig. 129) (Grabau. *Geol. soc. Am. Bul.* 11:368, pl. 22)

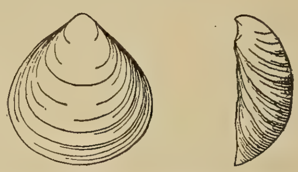


Fig. 129 Whitfieldella rotundata x 1½

Distinguishing characters. Small, subcircular; moderately convex; beak curved at right angles to plane of contact of valves.

Found in the Manlius limestone of Erie county (N. Y.)

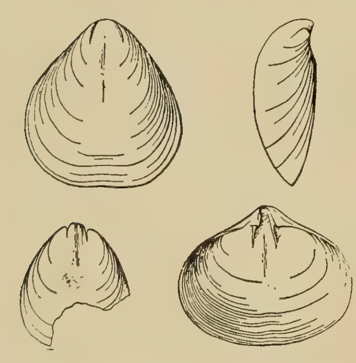


Fig. 130 Whitfieldella laevis x 1½

Whitfieldella laevis (Whitfield) (Fig. 130) (Grabau. *Geol. soc. Am. Bul.* 11:369, pl. 22)

Distinguishing characters. Small; broadly ovoid; moderately gibbous, greatest gibbosity in posterior third; faint mesial depression.

Found in the Manlius limestone of Erie county (N. Y.)

Genus HYATTELLA Hall & Clarke

[Ety.: proper name]

(1893. *Pal. N. Y.* v. 8, pt 2, p. 61)

Shell similar to W h i t f i e l d e l l a, but compactly subpentahedral, and without the median septum in the brachial valve.

Hyattella congesta (Conrad) (Fig. 131 and 131a). A t r y p a c o n g e s t a Hall (1852. *Pal. N. Y.* 2:67, pl. 23); A t r y p a q u a d r i c o s t a t a Hall (*Pal. N. Y.* 2:68, pl. 23)

Distinguishing characters. Subcircular; gibbous; strongly convex pedicle valve with deep median furrow, deepening and widening forward; frontal linguiform elevation, obtuse cari nated fold in sinus; strong fold on brachial valve, with a lateral fold on each side more or less prominent.

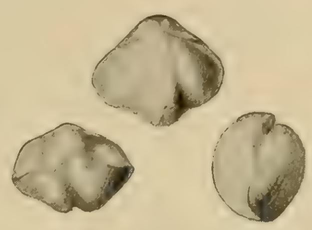


Fig. 131 Hyattella congesta

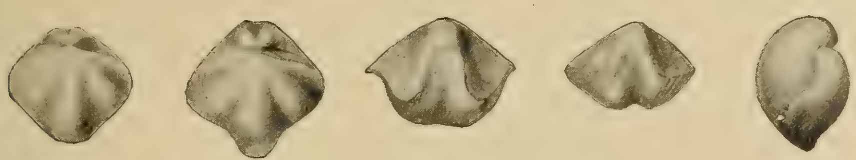


Fig. 131a Hyattella congesta

Found in the lower Clinton limestone at Niagara. Also at Lockport (Hall).

Genus ANOPLOTHECA Sandberger

[Ety.: ἄνοπλος, unarmed; θήκη, sheath]

(1853. *Sitzb. d. K. K. Akad. d. Wissens. math. naturw. Classe,* 16, p. 5, 18, 102; 1894. Hall & Clarke. *Pal. N. Y.* v. 8, pt 2, p. 129)

Concavo-convex, small shells with few plications crossed by fine often imbricating growth lines. Brachial valve with a high median septum. Brachidium a pair of spiral cones, as in Whitfieldella.

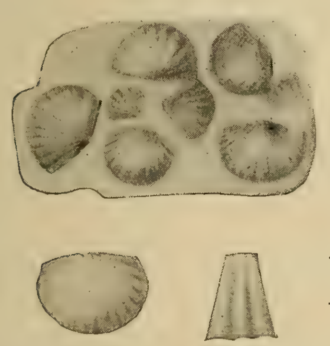


Fig. 132 Anoplotheca hemispherica with striae enlarged

Anoplotheca hemispherica (Sowerby) (Fig. 132). Atrypa hemispherica Hall (1852. *Pal. N. Y.* 2:74, pl. 23)

Distinguishing characters. Hemispheric to semiorbicular form; nearly flat brachial valve, convex pedicle valve; extended, nearly straight hinge line; eight to 12 rounded to subangular, simple plications; strong, undulating concentric striae.

Found poorly preserved in the Clinton shale at Niagara.

Anoplotheca plicatula (Hall) (Fig. 133). Atrypa plicatula Hall (1852. *Pal. N. Y.* 2:74, pl. 23)

Distinguishing characters. Slightly wider than long or sub-

rotund; cardinal slopes meeting in obtuse angle; young shell carinate toward the beak in the pedicle valve; brachial valve gently convex; median fold beginning as a depression at the beak, and becoming elevated near the front; two plications in sinus, three on fold; sharp rounded plications; strong frontal sinuosity; very fine concentric striae.

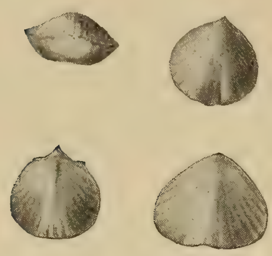


Fig. 133 Anoplotheca plicatula

Found in great abundance in the lower Clinton limestone at Niagara. Also east of Lockport (Hall).

Class PELECYPODA Goldfuss

(Lamellibranchiata Blainville)

The Pelecypoda, or Lamellibranchiata, are marine or fresh-water mollusks, with a bivalve shell. The valves are complementary, and in the majority of species are of nearly similar outline and size. In each valve may be distinguished an initial point, or beak, around which the concentric *lines of growth* mark the successive additions of shelly matter.

The orientation of most shells is effected by holding them with the *hinge line* uppermost and the beaks pointing away from the observer. Thus placed, the upper is the dorsal and the lower the ventral border. The end farthest away from the observer is the anterior end; that nearest, the posterior end. The valves are designated as the right and left valves respectively. The articulation of the valves is commonly effected by the interlocking of *teeth* which are borne on the hinge or cardinal margin of the valves. They vary greatly, but can usually be divided into the short, stout cardinal teeth, which are situated under or near the beak, and the ridge-like lateral teeth. The opening of the valves is brought about by an elastic ligament stretched across the hinge from valve to valve, behind the beak, which acts, on the principle of the C spring, whenever the tension of the *adductor muscles,* which close the valves, is relaxed. In many genera, an elastic, compressible cartilage, the

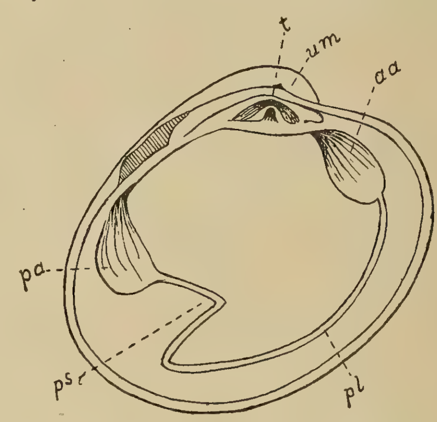


Fig. 134 Diagrammatic view of left valve of Cytherea; (aa) anterior adductor scars; (pa) posterior adductor scars; (pl) pallial line; (ps) pallial sinus; (t) teeth; (um) umbo; (l) ligament

resilium occurs, which is lodged in special grooves or pits. The scars marking the attachment of the adductor or closing muscle or muscles, vary greatly, and are frequently preserved in the fossil forms. When two are present, they are designated, respectively, the anterior and posterior adductor scars. The line of attachment of the fleshy mantle which builds the shells, i. e. the *pallial line,* is often visible. Near the posterior end it frequently makes a re-entrant curve—the *pallial sinus*—indicating that the animal had a retractile siphon. The various parts described are indicated in fig. 134.

The principal soft parts of the animal comprise: the *mantle*, consisting of two fleshy folds, one lining each valve, and building it; the *abdomen,* with the anteriorly placed *mouth,* and the antero-ventral *foot;* the *gills,* or *branchiae,* which consist of complicated lamellae hanging on either side of the abdomen in the mantle cavity; and the *siphons*—present only in certain forms—posteriorly placed, often capable of great extension, and serving, the one for the entrance of the water and food particles, and the other for the exit of the water and waste products.

Genus PTERINEA Goldfuss

[Ety.: πτερόν, wing]

(1826. *Petrefacta Germaniae,* p. 133)

Shell inequivalve, inequilateral; posterior side winged, anterior end nasute or with a well defined ear. Ligament internal; ligamental area longitudinally striated. Cardinal teeth two or more; lateral teeth linear oblique. Posterior muscular impression large, situated on the post-umbonal slope; anterior muscular impression small, situated within the rostral cavity. Test ornamented with rays.

Pterinea emacerata (Conrad) (Fig. 135). Avicula emacerata Conrad (Hall. 1852. *Pal. N. Y.* 2:228, pl. 59)

Distinguishing characters. Moderately oblique; large and posteriorly concave wing often extending beyond the shell below; small anterior ear; flat, smooth right valve with striated wing; convex left valve, with strong radii, interrupted by fainter concentric striae.

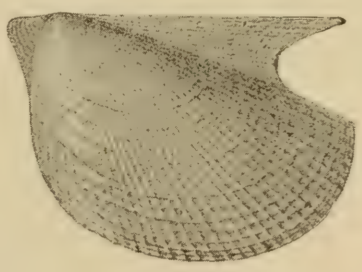


Fig. 135 Pterinea emacerata

Found perhaps in the Clinton shale, rarely in the lower and middle Rochester shale and abundantly in the upper shale. Niagara sections. Also at Lockport and elsewhere (Hall).

Genus LIOPTERIA Hall

[Ety.: λεῖος, smooth; πτερόν, wing]

(1883. *Pal. N. Y.* v. 5, pt 1, p. 4)

Shell aviculoid, oblique, subrhomboidal; anterior end not auriculate; wing large, extremity produced. Hinge narrow, furnished with a slender lateral tooth just posterior to the beak and nearly parallel to the hinge line. Ligament external; ligamental area narrow, extending the entire length of the hinge, marked by fine, sharp, longitudinal striae. Test with concentric striae but without rays.

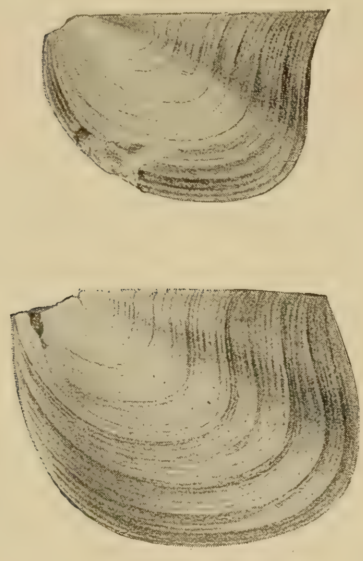


Fig. 136 Liopteria (?) subplana

Liopteria (?) subplana (Hall) (Fig. 136). Avicula subplana Hall (1852. *Pal. N. Y.* 2:283, pl. 59)

Distinguishing characters. Depressed convex surface; similarity of right and left valves; ill defined wing and ear; concentric striae; absence of radii.

Found in the Rochester shale at Lockport associated with Pterinea emacerata, etc. (Hall). Probably also at Niagara. The generic reference is provisional.

Genus LYRIOPECTEN Hall

[Ety.: λύριον, small lyre; *pecten,* comb, i. e. the genus Pecten]

(1884. *Pal. N. Y.* v. 5, pt 1, p. 12)

Shell inequivalve, with a short hinge line and very small anterior ear. Cartilage in shallow furrows, parallel to the hinge margin. Surface ornamented with rays.

Lyriopecten orbiculoides (nom. nov.) cf. Avicula (?) orbiculata Hall (1852. *Pal. N. Y.* 2:284, pl. 59)

Distinguishing characters. Right (?) valve convex; left (?) valve flat; form suborbicular, hinge line short, straight; strong radiating striae cancelated by equally strong concentric striae, forming surface similar to Pterinea emacerata.

Found in a loose block of limestone, probably the lower Lockport limestone, at Niagara. One specimen.

The identification with Hall's species and the generic reference are provisional.

Genus MODIOLOPSIS Hall

[Ety.: M o d i o l u s, a genus of recent shells; ὄψις, appearance (similar to)]

(1847. *Pal. N. Y.* 1:157)

Shells equivalve; valves elongate oval, closed, with nearly terminal beaks and narrow hinge plate, and without teeth; adductor scars subequal; ligament deep-seated.

Modiolopsis orthonota (Conrad) (Fig. 137) (Hall. 1852. *Pal. N. Y.* 2:10, pl. 4 bis)

Distinguishing characters. Subelliptic or rhomboidal form; straight hinge line; obliquely truncated anterior and rounded posterior ends; ventral and dorsal margins nearly parallel; elevated, thin, sharp umbones, with a faint ridge extending to the posterior basal margin; surface with concentric growth lines only.

Fig. 137 Modiolopsis orthonota

Found in the upper Medina sandstones at Niagara. Also in the same beds at Lockport, usually as molds.

Modiolopsis primigenia (Conrad) (Fig. 138) (Hall. 1852. *Pal. N. Y.* 2:10, pl. 4 bis)

Distinguishing characters. Subrhomboidal form; rounded anterior and expanded alate posterior ends; straight hinge line, produced posteriorly; rounded ventral margin; fine radiating striae visible only in well preserved shells; strong concentric growth lines.

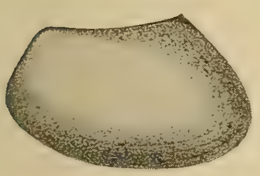


Fig. 138 Modiolopsis primigenia

Found usually as internal molds, in the upper Medina sandstones of the Niagara sections, and at Lockport and elsewhere.

Modiolopsis sp. (Compare M. s u b a l a t u s. *Pal. N. Y.* 2:84, pl. 27, fig. 5, 6; p. 285, pl. 59, fig. 7)

Distinguishing characters. A small left valve, strongly convex below the umbo; a strong cardinal ridge extends from beak to pos-

terior basal margin, and above this the surface of the posterior wing is slightly concave; beaks incurved, hardly raised above the hinge line; posterior end more sharply rounded than anterior; surface with concentric striae.

Found in the Clinton lenses on the Rome, Watertown and Ogdensburg railroad.

Class GASTROPODA Cuvier

The gastropods, or snails, are mollusks with a distinct head, a muscular foot, and a mantle consisting of a single lobe. They are terrestrial, marine, or fresh-water animals, and are commonly protected by a conic or spirally coiled shell, which is secreted by the mantle. The apical part of the shell usually consists of a simple coiled embryonic shell, or *protoconch*. Succeeding this is the shell proper, which, when coiled comprises few or many *whorls*, the later overlapping the earlier ones to a greater or less extent. The *suture* at the junction of the overlapping whorls may be faintly or strongly impressed. The whorls may coil closely, forming a compact central *columella*; or they may be loosely coiled, leaving a hollow columella, opening below in the *umbilicus*. The body whorl opens in the aperture, the rim or *peristome* of which consists of an *outer* and an *inner*, or *columellar lip*. The peristome is *complete* when both inner and outer lip are present, and *incomplete* when the place of the inner lip is taken by the preceding whorl. In a great many species the peristome is notched anteriorly, or produced into a straight, or more or less flexed canal. A posterior notch is also frequently found. The columellar lip and, in its absence, the columella, may be smooth or furnished with one or more plications. Similarly, the outer lip may be smooth on its inner side or furnished with plications or *lirae*. Among the external features of importance are the transverse *lines of* growth, which mark the successive increments; *varices* or rows of spines, parallel to the lines of growth, and marking periodic resting stages during the growth of the shell; and revolving longitudinal lines or ridges, which may be uniform or alternating, or may show a gradation in size. When transverse and longitudinal lines cross each other, a reticulated surface ornamentation is produced; and, when the shell is covered by an epidermis, or *periostracum*, hairlike spines not infrequently arise from the points of crossing. In Pleurotomaria and related gastropods, a siphonal notch occurs in the outer lip, and its progressive closure from behind leaves a marked revolving band, commonly visible only on the body whorl.

Many species, specially of marine gastropods, secrete a horny or calcareous *operculum*, which is attached to the foot, and closes the aperture of the shell when the animal is withdrawn. This is seldom preserved in a fossil state.

Genus PLATYCERAS Conrad

[Ety.: πλατύς, flat; κέρας, horn]

(1840. *An. rep't pal. N. Y.* p. 205)

Shell conic, irregular, with or without the apex inrolled; aperture expanded, often reflexed; peristome entire, often sinuous; surface variously striated, sometimes bearing spines.

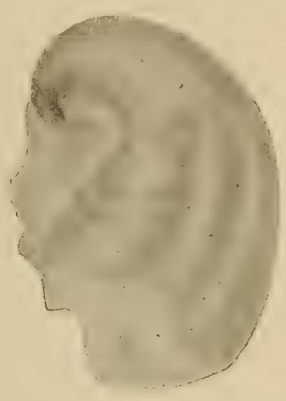


Fig. 139 Platyceras niagarense

Platyceras niagarense (Hall) (Fig. 139). Acroculia niagarensis Hall (1852. *Pal. N. Y.* 2:288, pl. 60)

Distinguishing characters. Involute apex, scarcely forming a volution; gradually expanding lower portion, with two or three longitudinal folds or undulations; transverse striae, which undulate across the folds and depressions.

Found rarely in the lower Rochester shale at Niagara. Also at Lockport (Hall).

Platyceras angulatum (Hall) (Fig. 140). Acroculia angulata Hall (1852. *Pal. N. Y.* 2:289, pl. 60)

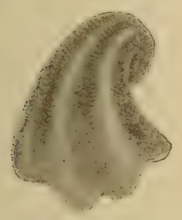


Fig. 140 Platyceras angulatum

Distinguishing characters. Attenuated apex, forming one or two minute volutions; shell below extending in a broad curve, and expanding rapidly toward the aperture, which is much dilated; angulated surface, with a sharp carina on the upper and lower outer margins, and an obtuse carina in the middle; transverse section unequally pentagonal.

Found in the lower and middle Rochester shale at Niagara. Rare. Also at Lockport (Hall).

Genus DIAPHOROSTOMA Fischer

[Ety.: διάφορος, unlike; στόμα, mouth]

(1885. *Manual de Conchyliologie;* Platyostoma Conrad. 1842. *Acad. nat. sci. Jour.* 8:275)

Shell with a short depressed spire, a large dilated aperture and with the inner lip lying close against the body whorl.

Diaphorostoma niagarense Hall (Fig. 141) (1852. *Pal. N. Y.* 2:287, pl. 60)

Distinguishing characters. Globose contour; three to four volutions; large body whorl, inflated toward the dilated aperture; deeply depressed sutures; fine longitudinal and strong transverse striae. Not infrequently a sinuosity is indicated by the lines of growth.

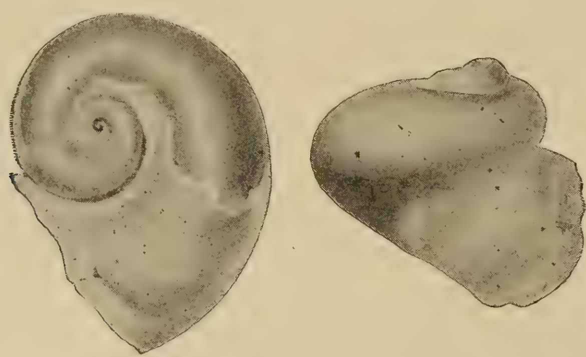


Fig. 141 Diaphorostoma niagarense

Found in the Clinton limestone lenses, and the lower and middle, and rarely the upper Rochester shale at Niagara. Also at Lockport and elsewhere (Hall).

Genus PLEUROTOMARIA De France

[Ety.: πλευρά, side; τομή, a cut]

(1824. *Tableau d. corps organises fossiles,* p. 114, and *Dict. sci. nat.* 41 :381)

Shell Trochus-shaped, more or less conic, with or without umbilicus; volutions angular, flattened, or rounded, their surfaces variously ornamented; aperture subquadrate to suborbicular, the inner lip thin. The outer lip bears a narrow, deep fissure or sinus, which is the unclosed continuation of a revolving band.

Pleurotomaria littorea Hall (Fig. 142) (1852. *Pal. N. Y.* 2:12, pl. 4 (bis))

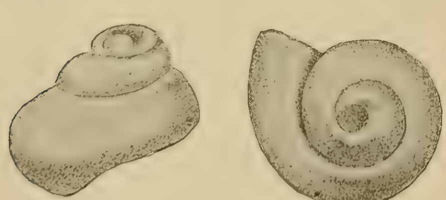


Fig. 142 Pleurotomaria littorea

Distinguishing characters. Medium size; subconical form; three to four somewhat obtusely angular volutions, which enlarge rapidly; small umbilicus.

Found in the upper Medina sandstone at Lockport (Hall). Fragments in the same rock at Niagara seem to be of this species.

Pleurotomaria pervetusta (Conrad) (Fig. 143) (1852. *Pal. N. Y.* 2:12, pl. 4 (bis))

Distinguishing characters. Small size; depressed conic spire, the volutions strongly embracing; whorls about four, gradually enlarging; large umbilicus extending to the apex.

Found in the upper Medina sandstones of the Niagara sections. Also at Lockport (Hall).

Fig. 143 Pleurotomaria pervetusta

Genus BUCANIA Hall

[Ety.: *bucina,* a trumpet]

(1847. *Pal. N. Y.* 1:32)

Shells coiled, a single plane, with the spire equally concave on either side and all the volutions visible; outer whorl ventricose; all whorls embracing to some extent, having an inner concavity; aperture rounded, oval, somewhat compressed on the inner side from contact with preceding whorl.

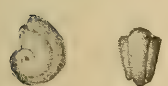


Fig. 144 Bucania trilobata

Bucania trilobata (Conrad) (Fig. 144) (Hall. 1852. *Pal. N. Y.* 2:13, pl. 4 (bis))

Distinguishing characters. Suborbicular form; three-lobed volutions, all of which are visible; last whorl greatly expanded; aperture wider than long.

Found at Medina and Lockport and fragments in the upper Medina of Niagara indicate its presence there.

Class CONULARIDA

Paleozoic mollusks of doubtful systematic position, resembling some modern Pteropoda, but only distantly and ancestrally related to them. Shells conic or tubular, elongate, septate and variously ornamented.

Genus CONULARIA Miller

[Ety.: diminutive of *conus,* a cone]

(1821. Sowerby. *Mineral conchology,* 3:107)

Shell elongated, pyramidal, with the transverse section varying from quadrangular to octagonal; angles indented by longitudinal grooves. The surface is variously ornamented by transverse or

reticulated striae. Near the apex the shell is furnished with a transverse septum.

Conularia niagarensis Hall (Fig. 145) (1852. *Pal. N. Y.* 2:294, pl. 65)

Distinguishing characters. Broad, pyramidal, tapering abruptly; deep abrupt channels of the angles; shallow, scarcely defined depression of centers of faces; fine and closely arranged transverse striae, which extend from the angles obliquely to the center, and

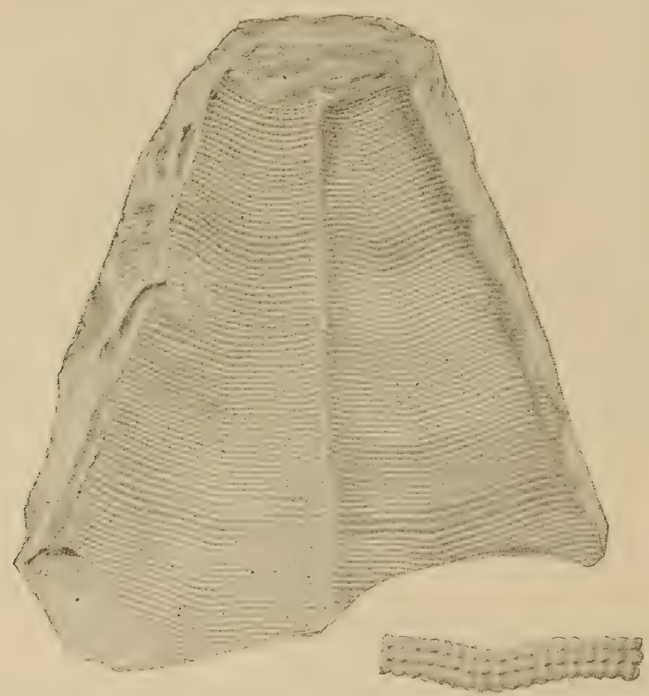


Fig. 145 Conularia niagarensis with several striae enlarged

bend more abruptly in crossing the central depression; granulate character of striae; intermediate spaces with longitudinal striae.

Found in the Rochester shale at Lockport (Hall). Probably occurs also at Niagara.

Class CEPHALOPODA Cuvier

The cephalopods are the most highly developed mollusks, possessing a distinct, well defined head, a circle of eight or more arms surrounding the mouth and generally furnished with suckers or hooks, a funnel-like *hyponome*, or swimming organ, and a highly developed nervous system. The majority of modern genera are naked, or with only a rudimentary internal shell (squids, cuttlefish, etc.). Nautilus is the only modern genus with a typical external shell.

The shells of cephalopods are chambered, i. e. divided, by a series of transverse floors or *septa*, into *air chambers*. The last or *living*

chamber lodges the animal. The septa are pierced by a corresponding series of holes, the walls of which are often prolonged backward or forward into *siphonal funnels,* the whole constituting the *siphuncle.*

In the Nautiloidea, the sutures are, as a rule, simple or but slightly lobed, and the siphuncle is commonly central or eccentric, but seldom marginal, with the funnels generally directed backward. The embryonic shell, or protoconch, is rarely retained.

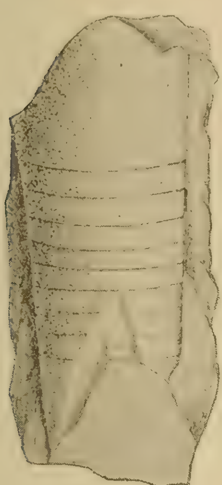


Fig. 146 Orthoceras multiseptum

The shells of cephalopods are either straight (more or less conic) or variously curved and coiled to close involution.

NAUTILOIDEA

Genus ORTHOCERAS Breyn

[Ety.: ὀρθός, straight; κέρας, horn]

(1732. *Dissertatio physica de polythalamiis*)

Shell a straight conic tube, with a large body chamber and numerous air chambers, separated by convex septa. Sutures simple, at right angles to the long axis of the shell; siphuncle central, subcentral, or eccentric, cylindric or sometimes widening in the chambers. Surface smooth or variously ornamented by transverse or longitudinal striae, or by annulations.

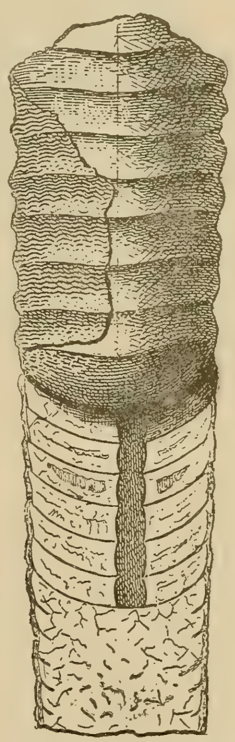


Fig. 147 Orthoceras annulatum. Terminal portion showing shell of living chamber and sectioned camerae (after Barrande)

Orthoceras multiseptum Hall (Fig. 146) (1852. *Pal. N. Y.* 2:14, pl. 4 (bis))

Distinguishing characters. Cylindric, gradually tapering; septa distant one sixth to one seventh the diameter.

Found in the upper Medina sandstone at Lockport, etc. (Hall). Probably also at Niagara.

Orthoceras annulatum Sowerby (Fig. 147). Orthoceras undulatum Hall (1852. *Pal. N. Y.* 2:293, pl. 64, 65)

Distinguishing characters. Strong annulations; moderately strong longitudinal lines which node the annulations, fine transverse striae; elliptic cross-section; subcentral siphuncle.

Found in the Clinton limestone lenses in the Rome, Watertown and Ogdensburg railroad cut above Lewiston. Also in the Roches-

ter shale and Lockport limestone at Lockport (Hall), and probably also at Niagara.

Orthoceras medullare Hall (1860. *Geol. sur. Wis. Rep't prog.* p. 4)

Distinguishing characters. Cylindric, gradually tapering form; septa distant nearly half the diameter; large siphuncle, slightly expanded between septa; strong sharp subequal longitudinal striae, with often alternating finer striae; smooth cast.

Found in the Clinton limestone lenses in the Rome, Watertown and Ogdensburg railroad section above Lewiston. Rare. The species is normally a western one.

Fig. 148 Cyrtoceras subcancellatum

Genus CYRTOCERAS Goldfuss

[Ety.: κυρτός, curved; κέρας, horn]

(1837. *De la Beche, Handb. d. Geogn. bearb. von v. Dechen.* p. 536)

Shell conic and gently curved, with a depressed elliptic to trigonal cross-section, the aperture in old shells contracted to a T-shaped opening; siphuncle large, eccentric.

Cyrtoceras subcancellatum Hall (Fig. 148). Cyrtoceras (?) cancellatum Hall (1852. *Pal. N. Y.* 2:290, pl. 61)

Distinguishing characters. Arcuate; transversely oval section; transversely striated surface, and faint longitudinal striae; siphuncle submarginal.

Found in the " limestone below the cliff at Niagara Falls " (Hall).

Genus GOMPHOCERAS Sowerby

[Ety.: γνόμφος, a pin, bolt, or club; κέρας, a horn]

(1839. Murchison. *Silurian system,* p. 620)

Shell straight or curved, pear-shaped, greatest diameter in front of the middle; cross-section circular; mouth contracted, opening by a T-shaped aperture; siphuncle central or eccentric, subcylindric or expanding between the septa (moniliform).

Gomphoceras ? sp. (Hall. 1852. *Pal. N. Y.* 2:290, pl. 61)

Distinguishing characters. Subfusiform aperture narrowed, gradually tapering to the extremity; surface striated transversely.

This fossil has the general form and appearance of Gomphoceras, though I am unable to discover any marks of septa. The greatest expansion appears to be at about one third of the distance from the aperture to the apex.

Found "in a fragment of limestone below the cliff at Niagara Falls" (Hall).

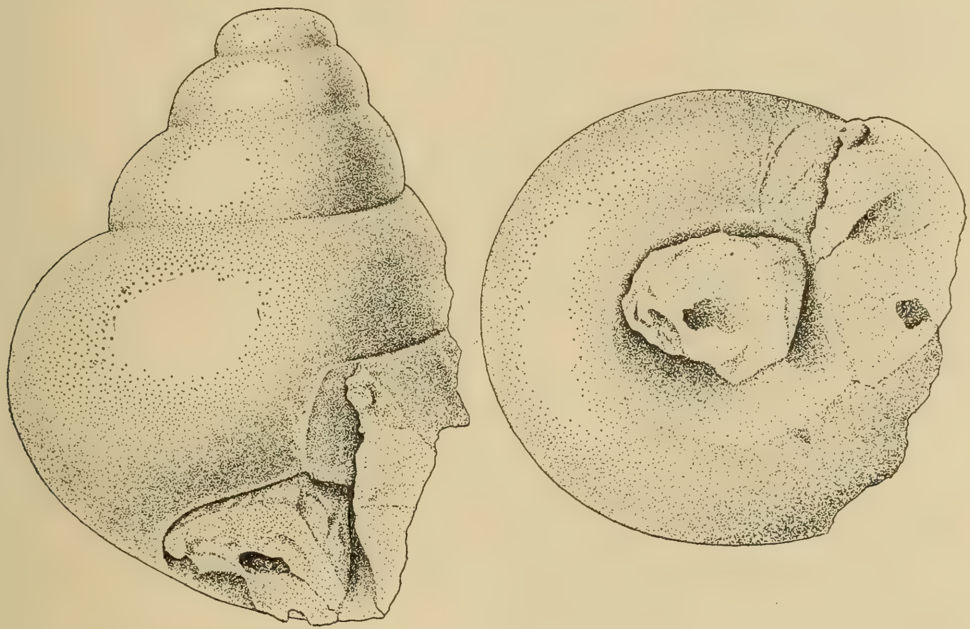


Fig. 149 Trochoceras gebhardi, two thirds natural size

Genus TROCHOCERAS Hall

[Ety.: τροχός, a wheel; κέρας, a horn (named from its trochus or top-like shape)]

(1852. *Pal. N. Y.* 2:335)

Shells turbinate or trochiform; spire elevated as in Gastropoda, more or less ventricose and umbilicated; aperture rounded or round oval; volutions above the outer one with septa; siphuncle submarginal or dorsal.

Trochoceras gebhardi Hall (Fig. 149) (1852. *Pal. N. Y.* 2:335, pl. 77, 77A; Grabau. *Geol. soc. Am. Bul.* 11:371, pl. 21)

Distinguishing characters. Deep and wide umbilicus with angular margins; cross-section of body whorl irregularly subhemispheric;

apical angle of spire about 60°; fine crowded surface striae. In the specimens so far obtained from the Manlius limestone, no septa have been preserved.

Found in the Manlius limestone of North Buffalo (Vogt & Piper, fig. 149) and Williamsville. The species was originally described from the Coralline limestone (Niagara) of Schoharie county (N. Y.)

Class CRUSTACEA Lamarck

Order OSTRACODA Latr.

The ostracods are small crustacea, with a bivalve, calcareous or horny shell covering the entire body. The valves are joined dorsally by a membrane, and open along the ventral side. The body is indistinctly segmented, and bears seven pairs of appendages, two pairs of which represent the trunk limbs. The shell corresponds to the carapace of the higher crustaceans. These organisms are minute and will ordinarily be overlooked unless search is made for them with a lens on the surfaces of the shale laminae. They are specially abundant in the finer grained shales.

Genus ISOCHILINA Jones

[Ety.: ἴσος, equal to; χεῖλος, lip]

(1858. *Can. organic remains,* Decade 3, p. 197)

Carapace with equal valves, whose margins meet uniformly and do not overlap; greatest convexity central, or toward the anterior end; anterior tubercle present.

Isochilina cylindrica (Hall). Cytherina cylindrica Hall (1852. *Pal. N. Y.* 2:14, pl. 4)

Distinguishing characters. Oval, elongate form; great convexity, "which, when both valves are joined, would give an almost cylindrical form to the shell".

Found in the upper Medina sandstones at Medina (Hall), but probably also at Niagara and other places.

Genus LEPERDITIA Rouault

[Ety.: Leperdit, proper name]

(1851. *Soc. geol. France. Bul.* ser. 2, 8:377)

Carapace with unequal valves, the right valve the larger and overlapping the left valve, along the ventral and, to some extent, along the anterior and posterior ends; valves smooth, oblong and horny.

Leperditia scalaris Jones (Fig. 150) (Grabau. *Geol. soc. Am. Bul.* 11:371, pl. 22)

Distinguishing characters. Bean-shaped outline; straight hinge line with salient angles; uniformly curved basal margin; anterior and posterior marginal borders; ocular tubercle about a third the length of the shell from the anterior end; strong, elongated fold or "dorsal hump" below the hinge line, in the posterior half of the left valve.

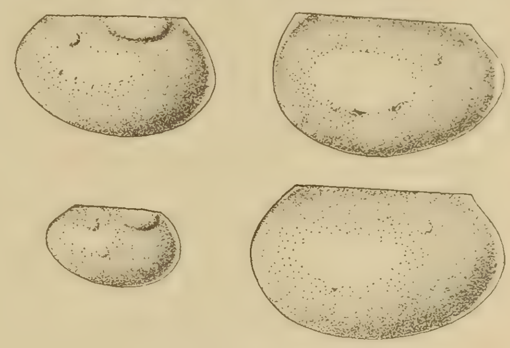


Fig. 150 Leperditia scalaris (enlarged)

Found in the Manlius limestone of North Buffalo and elsewhere in Erie county. It is a common species.

Genus BOLLIA Jones & Holl

[Ety.: Boll, proper name]

(1886. *An. and mag. nat. hist.*, ser. 5, 17:360)

Valves oblong, with rounded and nearly equal ends; hinge line straight, ventral margin curved; surface punctate and bearing a rudely horseshoe-shaped ridge, with a central depression within, and without a semilunar ridge on each side and parallel to the outer margins of the shell, which are slightly rimmed.

Bollia symmetrica (Hall) (Fig. 151). Beyrichia symmetrica Hall. (1852. *Pal. N. Y.* 2:317, pl. 67)

Distinguishing characters. Extremely small size; thin horseshoe ridge, dividing shell into three nearly equal parts; ridges and interspaces about equal; outer ridges not continued ventrally.

Fig. 151 Bollia symmetrica natural size and enlarged

Found in a fragment of weathered Rochester shale, on the talus along the Rome, Watertown and Ogdensburg railroad cut above Lewiston. Associated with the next. (One specimen found was larger than the normal, and the horseshoe curve rather thick ventrally, but not as thick as in B. lata of the Clinton group. This appears intermediate between the two species.) Also found at Lockport (Hall).

Genus AECHMINA Jones & Holl

[Ety.: αἰχμή, point of a spear]

(*An. and mag. nat. hist.* ser. 4. 3:217)

Carapace with thick valves, straight at hinge line, rounded at the ends, and convex at the ventral border. Surface drawn out into a broad-based and sharp pointed hollow cone, which either involves the whole surface, or rises from the postero-dorsal or centro-dorsal region.

Aechmina spinosa (Hall) (Fig. 152). Cytherina spinosa Hall (1852. *Pal. N. Y.* 2:317, pl. 67)

Fig. 152 Aechmina spinosa much enlarged After Jones

Distinguishing characters. Strong oblique spine, thick and hollow at the base, either elongate or short; pointed upward, outward and forward, and sometimes slightly bent; valves thickened on the free border by a raised, rounded but irregular margin; area at base of spine hollow and smooth; raised margin sometimes punctate; spine often long and projecting beyond the upper margin of the valve.

Found in weathered Rochester shale on the talus of the Rome, Watertown and Ogdensburg railroad cut above Lewiston. The valves are often imbedded in the shale with the inner concave surfaces exposed. Also found at Lockport (Hall).

Order TRILOBITA Burmeister

The trilobites are extinct Crustacea, wholly confined to the Paleozoic seas. The body was covered with a carapace longitudinally divisible into three parts. The anterior portion comprises the head-shield, or *cephalon*, which is usually semicircular, with a straight posterior border. The central of the three cephalic lobes is the *glabella*, which is the most prominent part of the cephalon. It is of varying outline, and more or less divided by transverse furrows or pairs of furrows. The last furrow is the *occipital furrow*, and delimits the *occipital ring*, which is just anterior to the first segment of the thorax. On either side of the glabella is a pair of cheeks, divided by the *facial suture* into *fixed cheeks* (those next to the glabella) and *free cheeks* (the outermost portion). The latter are often prolonged into

genal spines. The compound eyes are situated on the free cheeks, and they are overshadowed by more or less prominent eyelids or *palpebral lobes,* which are lateral lobes from the fixed cheeks. The facial suture thus passes between the eyes and the palpebral lobes, and when, as is often the case, the free cheeks become separated after the death of the animal, only the palpebral lobes remain on the central portion of the cephalon. The border of the cephalon is often distinctly marked, and is spoken of as the *cephalic limb.* At the margin it is folded down and under, making the *doublure,* which, continued backward, often produces hollow or solid genal spines. Near the anterior lower portion of the doublure lies the lower lip, or *hypostoma,* which is usually found separate.

The *thorax* consists of a varying number of segments or rings, articulated with each other, and commonly permitting enrolment. Each consists of a central *annulus* and lateral *pleurae.*

The tail, or *pygidium,* consists of a single piece, comprising a central *axis* and lateral *lobes.* The axis and the lobes commonly show transverse furrows, corresponding to the divisions of the thorax, and they are often so strongly marked that a line of division between thorax and pygidium is difficult to determine.

Great advances have recently been made in our knowledge of the ventral side of trilobites. Probably all of them had jointed appendages, which included antennae, mouth parts and legs, comparable in a general way to those of modern Crustacea.

Genus HOMALONOTUS Koenig

[Ety.: *ὁμᾰλός,* on the same level; *νῶτος,* back]

(1825. *Icones foss. sectiles,* p. 4)

Body usually large, depressed above, with abruptly sloping sides. The axial furrows are indistinct or obsolete. Cephalon depressed convex, wider than long, with rounded genal angles, and somewhat produced anterior margin; glabella almost rectangular, smooth, or with faint lateral furrows. Small eyes situated behind the middle, and converging facial sutures are characteristic. Thorax of 13 deeply grooved segments. Pygidium smaller than the cephalon, elongate triangular, rounded or produced posteriorly; axis with 10 to 14 annulations; lateral lobes smooth or with posteriorly sloping ribs.

Homalonotus delphinocephalus (Green) (Fig. 153) (Hall. 1852. *Pal. N. Y.* 2:309, pl. 68)

Distinguishing characters. Subtriangular cephalon; subquadrate glabella, widening a little posteriorly; small lateral eyes; acute anterior termination of cephalon; non-trilobate character of thorax, narrowing rapidly toward the posterior end; abruptly triangular pygid-

ium ending acutely, faintly trilobate, and strongly ringed both on the axial and lateral portions; granulose surface.

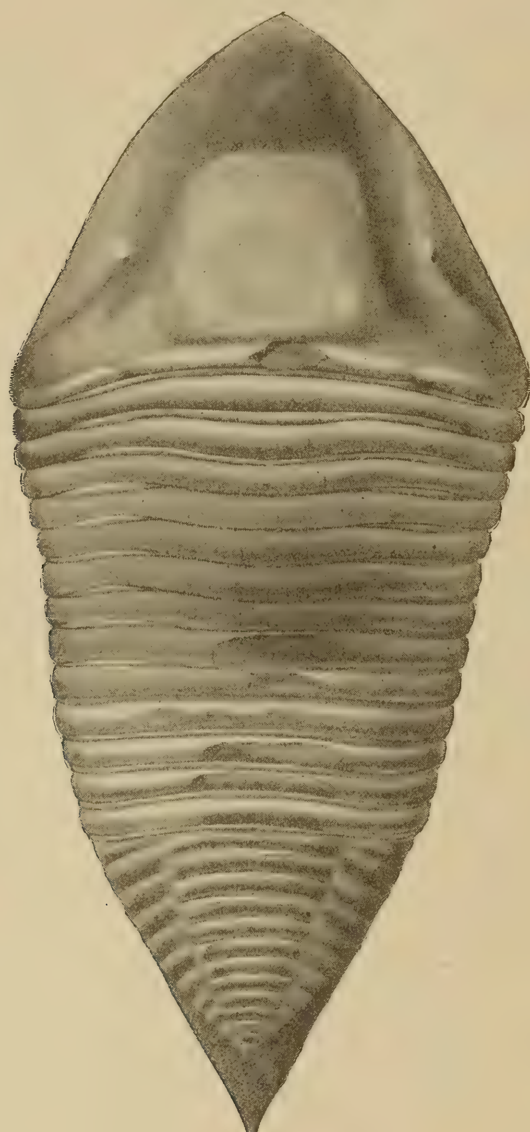


Fig. 153 Homalonotus delphinocephalus, ⅔ natural size

Found rarely in the lower Rochester shale at Niagara, but common in the upper shales. Also found at Lockport and elsewhere (Hall).

Genus ILLAENUS Dalman

[Ety.: ἰλλαίνω, to squint]

(1828. *Ueber die Palaeaden,* p. 51)

Cephalon and pygidium of about the same size, large and convex, smooth, semicircular in outline, with the trilobations faintly or not

at all marked in either. Glabella smooth, indistinct, eyes large, round, lateral cheeks small. Thorax usually consisting of 10 segments, with smooth pleurae.

Illaenus ioxus Hall (Fig. 154). Bumastis barriensis Hall (1852. *Pal. N. Y.* 2:302, pl. 66)

Distinguishing characters. Elongate elliptic form; rounded, nearly equal cephalon and pygidium, with the trilobation scarcely marked; large eyes near the posterior lateral border of the cephalon; faint trilobation of thorax with very broad central lobe; granulose or punctate surface.

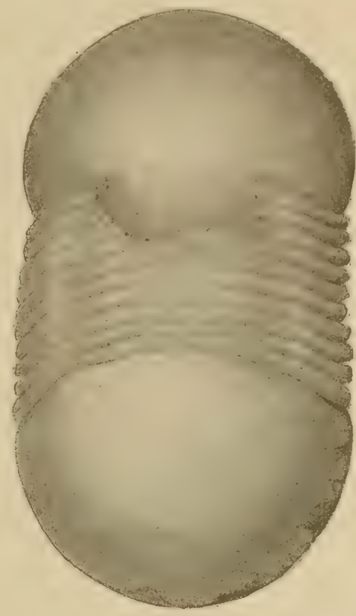


Fig. 154 Illaenus ioxus

Found in the Clinton limestone lenses in great abundance, usually represented only by cephala and pygidia. These are often crowded together in great profusion to the exclusion of nearly every other fossil. Also found rarely in the lower and middle Rochester shale at Niagara. Also found at Lockport and elsewhere (Hall).

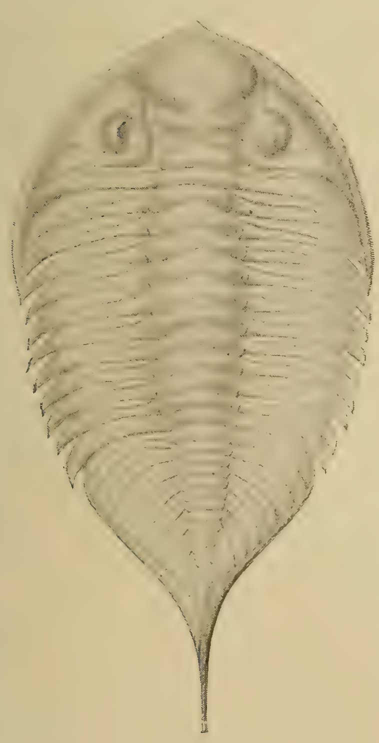


Fig. 155 Dalmanites limulurus

Genus DALMANITES Barrande

[Ety.: proper name]

(1852. *Système silurien Boh.* v. 1)

Cephalon distinctly trilobate, with a large glabella and prolonged lateral or genal spines; glabella tumid, widest in front, and divided by three well marked lateral furrows; facial suture extending from in front of the genal angles inward to the eyes and thence forward around the glabella; eyes large, with numerous distinct lenses. Thorax of 11 segments with grooved pleurae. Pygidium large, of many segments, triangular and often pointed or extended into a mucronate termination.

Dalmanites limulurus (Green) (Fig. 155). Phacops limulurus Hall (1852. *Pal. N. Y.* 2:303, pl. 67)

Distinguishing characters. Sublunate form of cephalon, pointed anteriorly; large slender genal spines; broad anterior and narrow posterior lobes of glabella; pygidium with 15 axial rings, and a long, strong mucronate spine.

Found rarely in the lower and middle but abundantly in the upper Rochester shales at Niagara. Also at Lockport and elsewhere (Hall).

Genus CALYMMENE Brongt.

[Ety.: κεκαλυμμένος, concealed]

(1822. *Hist. nat. corust. foss.* p. 7)

Body oval in outline, readily enrolled; cephalon wider than long; glabella narrowing anteriorly, conic, strongly convex, divided by three pairs of deep glabellar furrows. Facial sutures extending from just in front of the genal angles, converging forward around the eyes and reaching the anterior margin separately. Eyes small; thorax of 13 segments, with deep axial furrows; pygidium from six to 11 segments not distinctly marked off from the thorax.

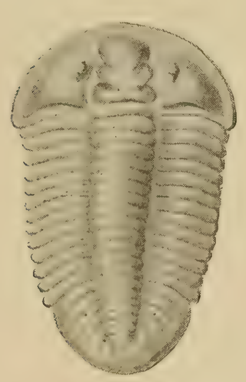


Fig. 156 Calymmene blumenbachi niagarensis

Calymmene blumenbachi niagarensis Hall (Fig. 156) (1852. *Pal. N. Y.* 2:307, pl. 67)

Distinguishing characters. Semicircular outline of cephalon; glabellar lobes tuberculiform; general tapering form of thorax; axis of pygidium with about eight rings; limb grooved nearly to margin, which is thickened and rounded posteriorly.

Found rarely in the Clinton limestone lenses, and the lower Rochester shale at Niagara. Also at Lockport (Hall).

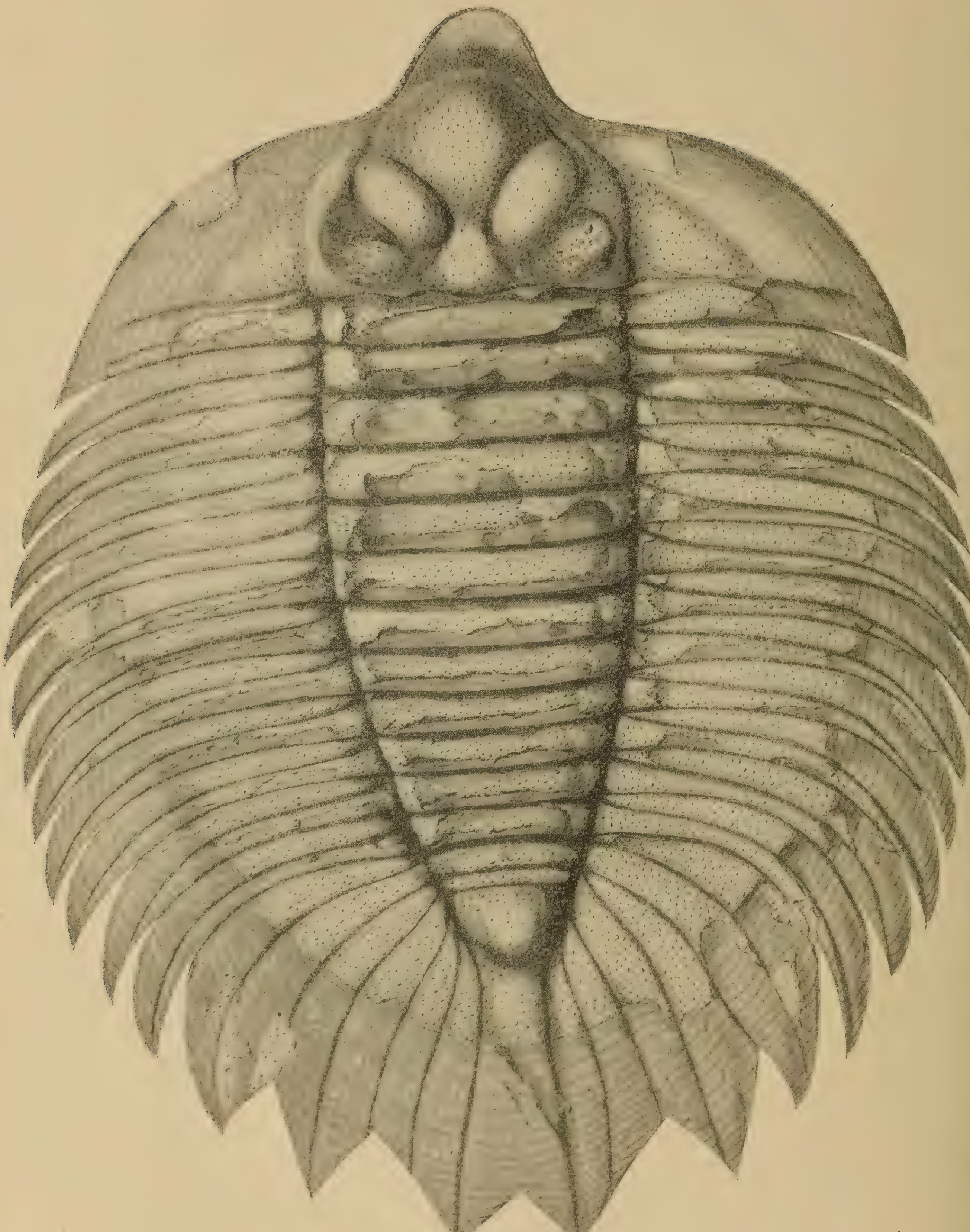
Genus LICHAS Dalman

[Ety.: mythologic name]

(1826. *Ueber die Palaeaden,* p. 71)

Trilobites with large and flat granulated shell. Cephalon small, with spinous genal angles; glabella broad, with a large, tumid anterior lobe, which dominates the smaller reniform lateral lobes on each side; eyes small; facial suture extending from the posterior

Plate 17



Lichas boltoni Bigsby; Rochester shale (After Hall)

margin obliquely inward to the eyes, and thence almost directly forward, cutting the margin separately. Thorax with nine or 10 segments and grooved and falcate pleurae. Pygidium large and flat, the segments commonly ending in spinous prolongations. Doublure very broad.

Lichas boltoni (Bigsby) (Plate 17) (Hall. 1852. *Pal. N. Y.* 2:311, pl. 69, 70)

Distinguishing characters. Large size; nasute anterior end; large central and oblique lateral lobes of glabella; scabrous surface with backward directed acute pustules; strongly striated doublure; three broad lateral lobes of pygidium, contracting to angular terminations.

Found in the lower Rochester shale at Niagara. Rare and in fragments. Common at Lockport and elsewhere (Hall).

Genus ENCRINURUS Emmrich

[Ety.: *encrinus; οὐρά* =tail (from the resemblance of the pygidium to a crinoid stem)]

(1845. *Neues Jahrb.* p. 42)

Cephaion narrow, wider than long, tuberculated; glabella pyriform, prominent; free cheeks narrow, separated in front; eyes small, elevated, on conic prominences. Thoracic segments 11. Pygidium triangular, with numerous segments.

Encrinurus ornatus Hall & Whitfield (Fig. 157). Cybele punctata Hall (1852. *Pal. N. Y.* 2:297, pl. A66)

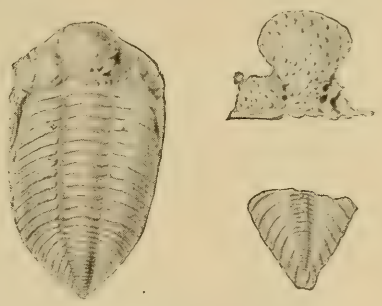


Fig. 157 Encrinurus ornatus

Distinguishing characters. Strongly pustulose surface of cephalon; pyriform glabella; elongate triangular pygidium, with concavity along the center of the axis, tuberculated at intervals; slender curving ridges of pygidial limb, tuberculated at intervals.

Found in the lower Clinton limestone at Niagara. Rare. Also at Lockport (Hall).

Genus BRONTEUS Goldfuss

[Ety.: mythologic name]

(1839. *Nova act. phys. med. caes. Leop. Carol. Nat. curios.* 19:360)

Dorsal shield broadly elliptic, with the cephalon less than one third the entire length; glabella rapidly expanding in front, with faint lobations. Thorax of 10 segments. Pygidium longer than cephalon or thorax, with a short axis and radiating furrows extending from it across the broad limb. Margin generally entire.

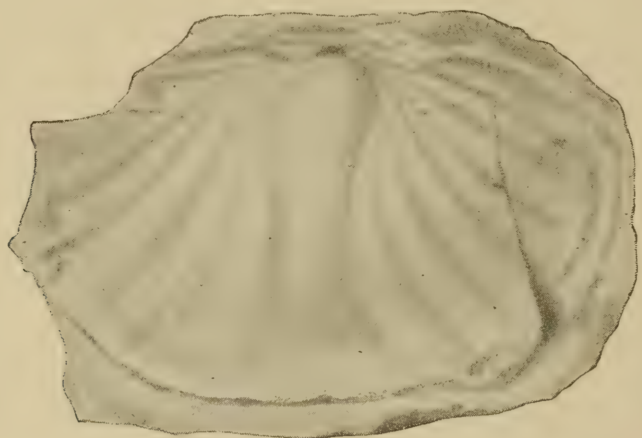


Fig. 158 Bronteus niagarensis; pygidium

Bronteus niagarensis Hall (Fig. 158) (1852. *Pal. N. Y.* 2:314, pl. 70)

Distinguishing characters. Pygidium only known; broad and somewhat semicircular; short axis and from six to nine long curving furrows or sulcations on either side of the center.

Found in "a large fragment of limestone in the Niagara river below the Canada fall" (Hall).

Order PHYLLOCARIDA Packard[1]

Crustacea with the body composed of five cephalic, eight thoracic, and two to eight abdominal segments. Head and thorax covered by a thin chitinous or semicalcareous single or bivalved shell or carapace. A narrow movable plate or *rostrum* lies in front of the caparace. Two pairs of antennae and stalked compound eyes present. Thoracic segments with soft leaf-like legs. Abdomen often ending in spiniform telson, provided with lateral spines.

[1] This section was revised by Prof. John M. Clarke, who also prepared the synopsis of species and synonymy.

Genus CERATIOCARIS McCoy

[Ety.: *κεράτιον*, pod; *καρίς*, shrimp]

(1849. *Ann. mag. nat. hist.* ser. 2, 4:412)

Carapace consisting of a smooth, pod-shaped bivalved shell, without eye nodes. Valves of carapace elongate, subovate, or subquadrate, truncated behind. A free lanceolate rostrum occurs. Body of 14 or more segments, of which from four to seven extend beyond the carapace. Some of these have obscure branchial appendages. Telson a long, pointed spine, with two smaller lateral spines (cercopods) articulated to it.

Ceratiocaris acuminata Hall (Fig. 159) (1859. *Pal. N. Y.* 3:422, pl. 84)

Distinguishing characters. Carapace large, tapering in front, broad medially and rather abruptly truncated on posterior margin. Surface with very fine, raised longitudinal lines. Penultimate segment long; telson and cercopods short.

Found in the Waterlime beds of North Buffalo.

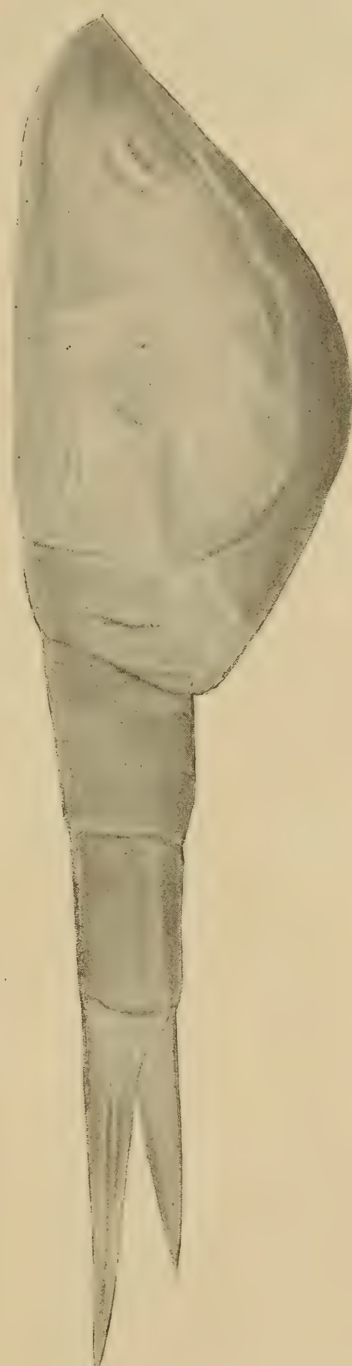


Fig. 159 Ceratiocaris acuminata, Hall

An essentially entire specimen with the various parts in their normal position. The large bivalved carapace is folded along the back and by the breaking away of a portion of the nearer or right side the margin of the other is exposed. Near the anterior extremity are shown a pair of mandibles or "stomach-teeth." The posterior portion of the carapace is seen to inclose several of the abdominal segments and of those which project, the last is very much the longest. Of the caudal spines, three in number, but two are here shown, the long central or telson and one of the lateral or cercopods. Two thirds natural size. From a specimen in the Museum of the Buffalo society of natural sciences.

Ceratiocaris (Phasganocaris?) deweyi Hall (Fig. 160) Onchus deweyi Hall (1852. *Pal. N. Y.* 2:320, pl. 71)

Distinguishing characters. Large spine of telson only

known; longitudinally grooved; periodic depressions or large pits in the grooves; shown as blunt spines on the rock mold.

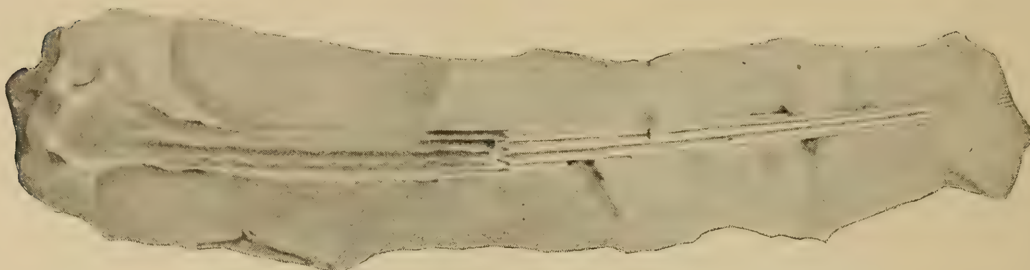


Fig. 160 Ceratiocaris (Phasganocaris ?) deweyi. Telson (reduced)

Found in the Lockport limestone at Niagara; also in the shale at Lockport (Hall).

Order EURYPTERIDA Burmeister

The eurypterids are large Crustacea, with an elongate body composed of cephalothorax, a ringed abdomen, and a tail piece or telson. The body is covered by a chitinous epidermal skeleton, and could be cast off as in the modern horseshoe crab (Limulus). The cephalothorax is usually furnished dorsally with two large, facetted lateral eyes, and a pair of median ocelli; and ventrally with six pairs of legs. The anterior joints or rings of the abdomen bear on their under side five pairs of broad, leaf-like appendages, which are comparable to the gills and operculum of the horseshoe crab. The posterior six segments are without appendages. The legs are comparable to those of Limulus and, like them, their inner margins are furnished with stout spines which serve as teeth. The last pair of legs is generally large, and usually somewhat flattened, and ends in an oval plate. This "paddle" may have been used for swimming purposes or for purposes of anchoring. On the under or ventral surfaces of the first two abdominal segments is the genital operculum, a pair of plates meeting medially, with a median lobe attached which differs in the two sexes.

Genus EURYPTERUS DeKay

[Ety.: εὐρύς, broad; πτερόν, wing]

(1825. *Lyc. nat. hist. N. Y. An.* 1:375)

Body elongate and narrow, often of great size. Cephalothorax one fifth or one sixth of the whole length, depressed convex, of a subquadrate outline with the anterior angles rounded, and the posterior margin slightly concave; entire margin bordered by a narrow marginal furrow. Eyes reniform, situated somewhat in front of the middle; ocelli close to the axial line. Mouth a ventral cleft. Legs

progressively increasing in length backward, the anterior pair with pincers or *chelae;* second, third and fourth pair six to seven-jointed, and covered with fine spines; fifth pair eight-jointed; posterior pair consisting of eight segments, large and powerful, with a large, subquadrate basal joint in each, and a broad terminal " paddle ". Anterior six abdominal segments occupying together about one fourth of the entire body length, short, broad and nearly uniform in shape. Succeeding six segments are ring-like, progressively decreasing in diameter, thus causing a tapering of the body. Telson long and slender.

Eurypterus lacustris Harlan (Hall. 1859. *Pal. N. Y.* 3:407*, pl. 81, 81A, 81B, 83B)

Distinguishing characters. Animal stout; anterior portion of the abdomen very broad, abruptly tapering beyond the sixth segment; penultimate segment quadrate, without lateral flanges.

Very abundant in the Waterlime of North Buffalo.

Eurypterus remipes De Kay (Plate 18) (Hall. 1859. *Pal. N. Y.* 3:404*, pl. 80, 80A, 83B)

Distinguishing characters. Animal small, with lateral body margins making broad outward curves and tapering very gradually backward. Penultimate segment slightly if at all flanged.

Occasionally in the Waterlime of North Buffalo.

Eurypterus pustulosus Hall (1859. *Pal. N. Y.* 3:413*, pl. 83B), Eurypterus giganteus Pohlman (*Buffalo soc. nat. sci. Bul.* 4:41)

Distinguishing characters. Cephalothorax large, short and very broad; eyes on the median transverse line; surface strongly pustulose.

A single specimen has been recorded from the Waterlime of North Buffalo.

Eurypterus robustus Hall, Eurypterus lacustis var. robustus Hall (1859. *Pal. N. Y.* 3:410*, pl. 81C)

Distinguishing characters. Like E. lacustris, but larger and more robust, and proportionately narrower over the anterior abdominal region.

Common in the Waterlime at North Buffalo.

Eurypterus pachychirus Hall (1859. *Pal. N. Y.* 3:412*, pl. 82)

Distinguishing characters. Similar to E. robustus; may prove identical. Terminal joints of the sixth pair of legs very broad.

Rare in the Waterlime at North Buffalo.

Eurypterus dekayi Hall (1859. *Pal. N. Y.* 3:411*, pl. 82)

Distinguishing characters. Proportionally short body; short broad carapace; anterior part of the abdomen very broad, posterior part much contracted. Penultimate segment with elongate lateral flanges.

Occasionally in the Waterlime at North Buffalo.

Genus DOLICHOPTERUS Hall

[Ety.: δολιχός, long; πτερόν, wing]

(1859. *Pal. N. Y.* 3:414*)

Distinguished from Eurypterus by having the sixth pair of cephalothoracic legs long and narrow, with the last two joints of subequal size. Metastoma elongate heart-shaped, as in Pterygotus.

Dolichopterus macrochirus Hall (1859. *Pal. N. Y.* 3:414*, pl. 83, 83A)

Distinguishing characters. Robust, elongated body, long, straight-sided carapace, very anterior eyes; strong and thick jointed anterior appendages; extremely long sixth pair of legs.

Found in the Waterlime beds of North Buffalo.

Genus EUSARCUS Grote & Pitt

[Ety.: εὖ, well; σάρξ, flesh (well-fleshed)]

(1875. *Buffalo soc. nat. sci. Bul.* 3:1)

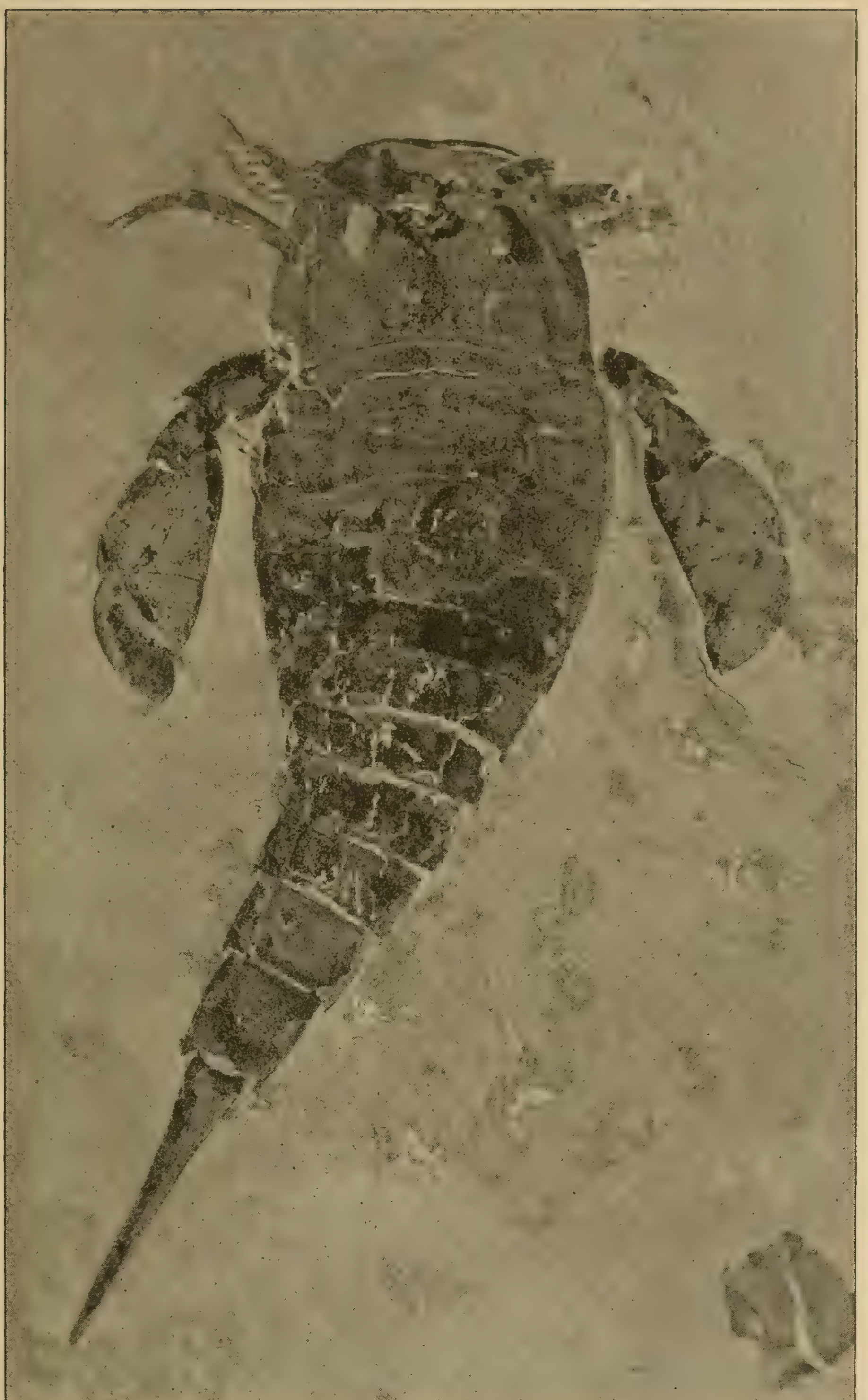
Eurypterids with the anterior six abdominal segments greatly expanded, and the succeeding ones abruptly contracted. The terminal joint of the sixth pair of legs is not expanded.

Eusarcus grandis Grote & Pitt (*Buffalo soc. nat. sci. Bul.* 3:17)

Distinguishing characters. Large size, attaining a length of 2 or 3 feet. Subcylindric posterior abdominal segments.

In the Waterlime at North Buffalo.

Plate 18



Eurypterus remipes DeKay; Rondout Waterlime, Buffalo (original)

Eusarcus scorpionis Grote & Pitt (*Buffalo soc. nat. sci. Bul.* 3:1)

Distinguishing characters. Smaller than the foregoing; average length about 1 foot. Appearance strikingly scorpioid. Telson strongly curved.

In the Waterlime at North Buffalo.

Genus PTERYGOTUS Agassiz

[Ety.: πτερύγωτός, winged]

(1839. Murchison. *Silurian system,* p. 605)

Large, often gigantic eurypterids, with a semiovate cephalothorax, anterior marginal eyes and central ocelli. The first pair of cephalothoracic legs (pre-oral) very long, slender, terminating in large pincers or chelae, and probably prehensile in function. Behind the mouth are four pairs of slender walking legs, and behind these are the large swimming feet, which differ from those of Eurypterus in being less broadly expanded at the ends. Telson an oval plate, either terminating in a short projecting point or bilobed.

Pterygotus macrophthalmus Hall (1859. *Pal. N. Y.* 3:418*), Pterygotus buffaloensis Pohlman (*Buffalo soc. nat. sci. Bul.* 4:17) and Pterygotus acuticaudatus Pohlman (*Buffalo soc. nat. sci. Bul.* 4:42)

Distinguishing characters. Cephalothorax subquadrate or tapering anteriorly; eyes very large and high, with circular base. Chelae (pincers) with angular front end; posterior denticles on larger ramus inclined and serrate.

In the Waterlime at North Buffalo.

Pterygotus cobbi Hall (1859. *Pal. N. Y.* 3:417*, pl. 83B, fig. 4), Pterygotus cummingsi Grote & Pitt (*Buffalo soc. nat. sci. Bul.* 4:18)

Distinguishing characters. Animal large; chelae (pincers) with curved front ends and erect non-serrate denticles.

Rare in the Waterlime at North Buffalo.

Pterygotus globicaudatus Pohlman (*Buffalo soc. nat. sci. Bul.* 4:42)

Distinguishing characters. Animal rather small; surface coarsely tubercled; telson circular without median keel.

A single specimen from the Waterlime of North Buffalo.

DISTRIBUTION OF FOSSILS IN THE SILURIC BEDS

Synopsis of strata:

Medina		1	Upper Medina sandstones and shales
Clinton beds		2	Clinton lower shale
Clinton beds		3	Clinton lower limestone (mainly lowest 4 feet)
Clinton beds		4	Clinton upper limestone (crystalline)
Clinton beds		5	Top beds of Clinton limestone
Clinton beds		6	Clinton lens. Niagara gorge
Clinton beds		7	Clinton lens. R. W. & O. railroad
Rochester shales	Lower shale	8	Lowest foot of shale
Rochester shales	Lower shale	9	Shale 3 feet above Clinton limestone
Rochester shales	Lower shale	10	Shale 4 feet above Clinton limestone
Rochester shales	Lower shale	11	Shale 5 feet above Clinton limestone
Rochester shales	Lower shale	12	Shale 6 to 8 feet above Clinton limestone
Rochester shales	Lower shale	13	Shale 19 feet above Clinton limestone
Rochester shales	Lower shale	14	Shale 25 feet above Clinton limestone
Rochester shales	Lower shale	15	Bryozoa beds
Rochester shales	Upper shale	16	Upper shales
		17	Lockport limestones
		18	Waterlime, Buffalo
		19	Manlius limestone

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Plants																			
Bythotrephis gracilis	....	rc	rc	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
B. lesquereuxi	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	r	....
Arthophycus harlani	[1]c	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Nematophycus crassus	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	r
Hydrozoa																			
Dictyonema retiformis	....	....	....	....	....	....	....	....	....	r	....	r	....	....	....	....	....	....	....
Stromatopora concentrica	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	c	....	....
Anthozoa																			
Enterolasma caliculus	....	....	....	....	r	c	?	rc	....	c	....	....	....	....	r	....	....	....	....
Zaphrentis turbinata	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	?	....	....
Cyathophyllum hydraulicum	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	cc
Chonophyllum niagarense	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Diplophyllum caespitosum	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Favosites venustus	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	c	....	....
F. parasiticus	....	....	....	....	....	....	....	....	....	....	....	....	....	....	rc	....	....	....	....
F. pyriformis	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
F. constrictus	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
F. niagarensis	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	c	....	....
Halysites catenulatus	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	rc	....	....
Heliolites elegans	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
H. spinipora	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
H. pyriformis	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Cladopora seriata	....	....	....	....	....	....	....	....	....	....	....	....	....	....	rc	....	....	....	....
C. multipora	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Striatopora flexuosa	....	....	....	....	....	....	....	....	....	....	....	....	....	....	rc	....	....	....	....
Cystoidea																			
Caryocrinus ornatus	....	....	....	....	....	....	....	....	....	c	....	....	r	c	rc	....	....	....	....
Callocystites jewetti	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Crinoidea																			
Stephanocrinus angulatus	....	....	....	....	....	....	....	r	....	c	....	....	....	c	r	....	....	....	....
S. gemmiformis	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....

[1] rr very rare; r rare; rc moderately common; c common; cc very common.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Crinoidea (continued)																			
Thysanocrinus liliiformis	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Lyriocrinus dactylus	....	....	....	....	....	....	....	....	....	....	....	....	....	?	....	....	....	....	....
Glyptocrinus plumosus	....	....	....	rc	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Eucalyptocrinus decorus	....	....	....	....	....	r	....	....	....	....	....	rc	....	rc	?	....	rc	....	....
Ichthyocrinus laevis	....	....	....	....	....	....	....	....	....	....	....	....	....	rc	....	....	....	....	....
Lecanocrinus macropetalus	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Annelida																			
Cornulites bellistriatus	....	....	....	....	....	....	....	....	....	....	....	....	....	....	?	....	....	....	....
Bryozoa																			
Diploclema sparsum	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Ceramopora imbricata	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
C. (?) incrustans	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Chilotrypa ostiolata	....	....	....	....	....	....	....	....	....	....	....	....	....	c	rc	....	....	....	....
Batostomella granulifera	....	....	....	....	....	....	....	....	....	....	....	....	....	r	....	....	....	....	....
Lioclema florida	....	....	....	....	....	....	....	....	....	....	....	....	....	....	r	....	....	....	....
L. aspera	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Trematopora tuberculosa	....	....	....	....	....	....	....	....	....	....	....	....	....	....	c	....	....	....	....
T. (?) striata	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Callopora elegantula	....	....	....	....	....	....	....	....	....	....	....	....	....	....	cc	....	....	....	....
Phylloporina asperato-striata	....	....	....	....	....	....	....	....	....	....	....	....	r	....	c	....	....	....	....
Drymotrypa diffusa	....	....	....	....	....	....	....	....	....	....	....	....	....	r	r	....	....	....	....
Fenestella elegans	....	....	....	....	....	....	....	....	....	....	....	....	....	....	rc	....	....	....	....
Semicoscinium tenuiceps	....	....	....	....	....	....	....	....	....	....	....	....	....	....	rc	....	....	....	....
Polypora incepta	....	....	....	....	....	....	....	....	....	....	....	....	....	....	c	....	....	....	....
Helopora fragilis ?	cc	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Clathropora frondosa	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
C. alcicornis	....	....	....	....	....	....	....	....	....	r	....	....	....	r	r	....	....	....	....
Rhinopora tuberculosa	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Diamespora dichotoma	....	....	....	....	....	....	....	....	....	....	....	....	....	....	rc	....	....	....	....
Lichenalia concentrica	....	....	r	....	....	c	c	....	....	r	....	....	r	....	r	....	....	....	....
Brachiopoda																			
Lingula cuneata	c	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Pholidops squamiformis	....	....	....	....	....	....	....	....	....	....	....	....	....	rc	....	....	....	....	....

Dictyonella corallifera															r				
Leptaena rhomboidalis					r	r	r			c	r		rc	c	c	r			
Stropheodonta corrugata				?		r									?				
S. profunda			c	rc															
Strophonella striata															r	rc			
S. (?) patenta			r	?	c	r									?				
Plectambonites sericeus			r																
P. transversalis						rc		r	c	c	rc		r		r				
Orthothetes subplanus					rc	rc				?		r	?	c	rc	rc			
O. hydraulicus																			c
Chonetes cornutus																?			
Orthis flabellites					r					r					?				
O. (?) punctostriata															?				
Orthostrophia (?) fasciata												?							
Dalmanella elegantula						rc			c	rc				r	cc				
Rhipidomella hybrida														rc	c	r			
R. circulus			?																
Scenidium pyramidale																			
Anastrophia interplicata						r			?				?	r	rc				
A. brevirostris												?							
Pentamerus oblongus				rr															
Barrandella fornicata				rc															
Rhynchotreta cuneata americana						rc	r			r			rc	rc	c	r			
Camarotoechia obtusiplicata										r					?				
C. neglecta			rc			rc	r						rc	r	c	rc			
C. acinus				rc															
Rhynchonella robusta					r														
R. (?) bidens																			
R. (?) bidentata																			
Atrypa reticularis				cc	c	rc	r	r	r	c		r		r	rc				
A. nodostriata						c	rc	rc	r	rc				rc	cc				
A. rugosa				r		rc	?	r		rc				rc	rc				
Cyrtina pyramidalis																			
Spirifer radiatus				rc	rc	c	r	r		c		r	rc	r	rc				
S. niagarensis					rc	c		r	rc	c	r	c	r	c	c				
S. crispus						r			rc	r	r			c	cc				
S. crispus corallinensis				rc			r			rc									
S. eriensis																			rc
S. (Delthyris) sulcatus						r	r			r				rc	rc				

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Brachiopoda (continued)																			
Homoeospira apriniformis	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Trematospira camura	....	....	....	....	....	....	....	....	....	....	....	....	....	....	c	....	....	....	....
Whitfieldella nitida	....	....	....	....	....	cc	rc	....	....	rc	....	rc	r	rc	c	....	....	....	....
W. nitida oblata	....	....	....	....	rr	cc	....	rc	....	c	....	rc	....	c	rc	....	....	....	....
W. oblata	r	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
W. intermedia	....	....	....	....	....	c	....	rc	....	?	....	....	....	....	....	....	....	....	....
W. cylindrica	....	....	....	....	....	....	....	....	....	r	....	....	....	....	....	....	....	....	....
W. sulcata	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	rc
W. rotundata	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	r
W. laevis	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	rc
Hyattella congesta	....	....	r	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Anoplotheca hemispherica	....	c	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
A. plicatula	....	....	cc	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Pelecypoda																			
Pterinea emacerata	....	?	....	....	....	....	....	....	....	....	....	....	....	....	r	c	....	....	....
Liopteria (?) subplana	....	....	....	....	....	....	....	....	....	....	....	r	....	....	....	....	....	....	....
Lyriopecten (?) orbiculoides	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	rr	....	....
Modiolopsis orthonota	c	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
M. primigenia	rc	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Modiolopsis sp	....	....	....	....	....	....	r	....	....	....	....	....	....	....	....	....	....	....	....
Gastropoda																			
Platyceras niagarense	....	....	....	....	....	....	....	....	....	....	....	....	....	....	?	....	....	....	....
P. angulatum	....	....	....	....	....	....	....	....	....	r	....	....	....	r	rc	....	....	....	....
Diaphorostoma niagarense	....	....	....	....	....	r	....	....	....	r	....	r	....	rc	c	r	....	....	....
Pleurotomaria littorea	?	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
P. pervetusta	rc	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Bucania trilobata	?	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Conularida																			
Conularia niagarensis	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....

Cephalopoda																			
Orthoceras multiseptum	?																		
O. annulatum							rc										r		
O. medullare							r										r		
Cyrtoceras subcancellatum																			
Gomphoceras sp																			r
Trochoceras gebhardi																			
Ostracoda																			
Isochilina cylindrica	r																		
Leperditia scalaris																			c
Bollia symmetrica															?				
Aechmina spinosa															?				
Trilobita																			
Homalonotus delphinocephalus														r		c			
Illaenus ioxus						c	cc			r		r			r				
Dalmanites limulurus												r	r		r	cc			
Calymmene blumenbachi niagarensis						r									r	?			
Lichas boltoni														r					
Encrinurus ornatus			r																
Bronteus niagarensis																	r		
Phyllocarida																			
Ceratiocaris acuminata																		rc	
C. deweyi																	r		
Eurypterida																			
Eurypterus lacustris																		cc	
E. remipes																		rc	
E. pustulosus																		rr	
E. robustus																		c	
E. pachychirus																		r	
E. dekayi																		rc	
Dolichopterus macrochirus																		rc	
Eusarcus grandis																		rc	
E. scorpionis																		rc	
Pterygotus macrophthalmus																		rc	
P. cobbi																		r	
P. globicaudatus																		rr	

Chapter 5

POST-PLIOCENE FOSSILS OF THE NIAGARA RIVER GRAVELS

BY ELIZABETH J. LETSON[1] DIRECTOR OF THE MUSEUM OF THE BUFFALO SOCIETY OF NATURAL SCIENCES

The post-Pliocene shells in the gravel beds of the Niagara river have long been known, but never before been fully described. The localities at which shell-bearing gravels have thus far been found are Goat island, Prospect park, Queen Victoria park, Muddy creek, whirlpool (both sides of the river), and at Foster's flats. The shells occur, generally, intimately mixed with the sand and gravel, showing that they were transported to the present localities by currents and eddies. The same action, taking place in recent times, may be witnessed at the lower end of Goat island, where the dividing water washes the shells into the pockets and crevasses in the rock.[2]

The following table shows the distribution of these shells in the various deposits, and also where these forms may be found living today.

NAME OF SPECIES	Goat island	Prospect park	Queen Victoria park	Muddy creek	Whirlpool, American side	Whirlpool, Canadian side	Foster's flats	Living in Niagara river	Living elsewhere
Gastropoda									
1 Pleurocera subulare Lea	x	----	----	----	----	----	----	x	----
2 Goniobasis livescens (Menke)	x	x	x	x	x	x	----	x	----
3 G. livescens niagarensis (Lea)	x	----	----	----	----	----	----	x	----
4 G. haldemani Tryon	x	----	----	----	----	----	----	----	*c*
5 Amnicola limosa (Say)	x	----	----	----	----	----	x	----	----
6 A. letsoni Walker	x	----	----	----	----	----	----	----	----
7 Bythinella obtusa (Lea)	x	----	----	----	----	----	----	----	*b*
8 Pomatiopsis lapidaria (Say)	----	----	----	----	----	x	x	x	----
9 Valvata tricarinata Say	x	----	----	----	----	----	x	x	----
10 V. sincera Say	x	----	----	----	----	----	----	----	*a*
11 Campeloma decisa Say	x	----	----	----	----	----	x	----	----
12 Limnaea columella Say	x	----	----	----	----	----	----	----	*a*
13 L. desidiosa Say	x	----	----	----	----	x	x	----	----
14 L. catascopium Say	x	----	----	----	----	x	x	----	----
15 Physa heterostropha Say	x	----	----	----	----	x	x	----	----
16 Planorbis bicarinatus Say	x	----	----	----	----	----	x	----	----
17 P. parvus Say	x	----	----	----	----	----	x	----	----

a Lime lake.
b Chippewa creek.
c Living, but not within a radius of 50 miles.

[1] I wish to acknowledge here my obligations to Prof. Henry A. Pilsbry, Mr Bryant Walker and Dr V. Sterki, for valuable assistance and advice given in the preparation of this chapter.

[2] *See also* Chapter 2, Goat island gravels.

NAME OF SPECIES	Goat island	Prospect park	Queen Victoria park	Muddy creek	Whirlpool, American side	Whirlpool, Canadian side	Foster's flats	Living in Niagara river	Living elsewhere
Pelecypoda									
18 Sphaerium striatinum (Lam.)	x	x	x	----	x	------	x	x	----
19 S. stamineum (Conrad)	x	x	------	----	------	x	----	x	----
20 Pisidium virginicum Bourg.	x	----	------	----	------	------	----	------	*b*
21 P. compressum Prime	x	----	------	----	------	------	----	------	*b*
22 P. abditum Haldeman	x	----	------	----	------	------	----	------	*a*
23 P. ultra-montanum Prime	x	----	------	----	------	------	----	------	*a*
24 P. scutellatum Sterki	x	----	------	----	------	------	----	------	*a*
25 Lampsilis rectus (Lam.)	x	----	------	----	------	------	----	x	----
26 L. ellipsiformis (Conrad)	----	x	------	----	------	------	----	x	----
27 Alasmidonta calceola (Lea)	x	----	------	----	------	------	----	x	----
28 A. truncata (Wright)	x	----	------	----	------	------	----	x	----
29 Unio gibbosus Barnes	x	x	x	x	------	x	x	x	----
30 Quadrula solida (Lea)	----	x	------	----	------	------	----	x	----
31 Q. coccinea (Conrad)	x	x	x	x	------	x	x	x	----

a Lime lake.
b Chippewa creek.
c Living, but not within a radius of 50 miles.

Class GASTROPODA Cuvier

Genus PLEUROCERA Rafinesque. 1819

Shell lengthened and conical, aperture moderately prolonged into a short spout or canal in front. The columella is not thickened.

Pleurocera subulare Lea (Fig. 161) (*Philos. soc. Trans.* 4:100)

Shell large and heavy, elevated and turreted, having an acute apex; nine to 11 whorls, flat, shouldered at the suture, which is impressed; body whorl surrounded by three ridges, the middle being the most prominent; aperture small, lip thin, folding back over the columella and covering the umbilical tract.

Locality. Goat island.

Fig. 161 Pleurocera subulare

Genus GONIOBASIS Lea. 1862

Shell heavy, elongated or ovate, aperture plain, slightly angulated in front.

Goniobasis livescens (Menke) Tyron 1873 (Fig. 162). Melania livescens Menke (1830. *Syn. meth.* p. 135)

Goniobasis livescens Tryon (1873. *Smith. Misc. coll. no.* 253, p. 248)

Fig. 162 Goniobasis livescens

Shell oblong and ovate; six or seven whorls; early volutions slightly keeled; spire acute; sutures impressed; whorls convex and crossed by plainly marked growth lines; lip moderately thin, and thin callous on the columella.

This is the most common of all the shells occurring in these deposits along the Niagara river; it is subject to great variation.

Localities. Goat island, Prospect park, Whirlpool, etc.

Goniobasis livescens var. **niagarensis** (Lea) Tryon 1873 (Fig. 163). Melania niagarensis Lea (1841. *Philos. soc. Phil. Proc.* 2:12). Goniobasis livescens var. niagarensis Tryon (*Smith. Misc. coll.* no. 253, p. 248)

Shell conic, obtuse, thick and smooth; spire short, whorls five or six, surrounded by a sharp keel, which clearly marks the suture; aperture elliptic; lip thin; columella slightly calloused.

Fig. 163 Goniobasis livescens *var.* niagarensis

Prof. H. A. Pilsbry, who examined these shells, writes: "This remarkable form differs from G. livescens, and var. niagarensis, in the persistence of the peripheral keel to the adult stage, producing a shell contour similar to Anculosa carinata; it has not hitherto been described or noticed in conchological literature, and would be entitled to specific rank were it not connected by intermediate forms with var. niagarensis".

Locality. Goat island.

Fig. 164 Goniobasis haldemani

Goniobasis haldemani Tryon 1865 (Fig. 164). G. haldemani Tryon. (1865. *Am. jour. conch.* 1:38)

Shell elongated, narrow and rather thin; eight or nine whorls, which are flat, smooth and separated by a slightly impressed suture; aperture small, subrhomboidal; lip thin, moderately incurved on the columellar side.

This graceful shell is very scarce and is not represented in the recent fauna.

Locality. Goat island.

Genus AMNICOLA Gould & Haldeman. 1841

Shell small, short, subglobular, and ovate; spire obtuse; shell smooth, thin and perforate; aperture ovate; lip thin; operculum corneous.

Amnicola limosa (Say) Hald. 1844. Paludina limosa Say (1817. *Acad. nat. sci. Phil. Jour.* 1:125). Amnicola limosa Haldeman (1844. *Monograph* pl. 1, fig. 5, 6)

Shell small and conic; whorls four, rapidly diminishing; apex acute, suture deep; umbilicus narrow and deep; surface smooth; recent specimens show growth lines; aperture oval, slightly angulated at the junction of the body whorl; lip simple.

Found in the gravel pit on Goat island.

Amnicola letsoni Walker 1901 (Fig. 165)

A. letsoni Walker (Feb. 1901. *Nautilus*)

Shell small, elevated and thick; whorls four or five, more or less flattened, and inclined to be shouldered; suture deep; spire short, less than one third the entire length; apex obtuse; aperture small and oval, angled above, rounded below, flattened on the parietal margin; lip thick and free from contact with the body whorl.

Fig. 165 Amnicola letsoni x3

Locality. Goat island.

In his notes Mr Walker says: "Amnicola sheldoni Pils. is the only species with which this can be compared. The present species is to be distinguished by its flattened, shouldered whorls, deeper suture and more acuminate spire. Six mature examples were found, which, though differing somewhat in the relative proportions of length and width, are as a whole quite uniform. In four of them the peristome is distinctly separated from the body whorl; in one, while continuous, it is so close as to be almost adnate, while in the remaining specimens the parietal margin, although somewhat broken, seems to have been appressed to the body whorl for a short distance. Associated with these specimens were two other examples quite similar, but much more cylindrical in the outline, less solid, and with the aperture less angled posteriorly. Neither is quite mature, judging from the thinness of the lip. In view of the considerable variation in these particulars in other well-known species of the genus, such as Amnicola lustrica Pils., and of the few specimens now at hand, it is not deemed advisable at the present time to do more than call attention to the fact."

What may prove to be other species of Amnicola has been found, but too badly worn to justify description.

Genus BYTHINELLA Moquin-Tandon. 1855

Shell elongated and pyriform; imperforate; apex obtuse; aperture oval; lip simple; operculum corneous.

Bythinella obtusa (Lea) Binney 1865 (Fig. 166). Paludina obtusa Lea (1844. *Philos. soc. Phil. Trans.* 9:13). Bythinella obtusa Binney (1865. *Smith. Misc. coll.* no. 144, p. 70)

Fig. 166 Bythinella obtusa. x3

Shell small, subcylindric, comparatively thin; five whorls; spire very short, giving the shell a truncated appearance; apex obtuse; sutures well defined; delicate growth lines may be seen with a lens; the aperture is small and round; the umbilicus narrow and deep.

Found in the Goat island gravel pits.

Genus POMATIOPSIS Tryon. 1862

Animal with a broad, short foot, and short pointed tentacles. Shell thin and smooth, having a produced spire; aperture oval, and provided with an operculum.

Pomatiopsis lapidaria (Say) Tryon 1862 (Fig. 167). Cyclostoma lapidaria Say (1817. *Acad. nat. sci. Phil. Jour.* 1:13). Pomatiopsis lapidaria Tryon (1862. *Acad. nat. sci. Phil. Proc.* p. 452)

Shell conic; spire high, seven whorls, well rounded and transversely wrinkled; sutures impressed; aperture rounded and about one third the length of the shell; subumbilicate.

Fig. 167 Pomatiopsis lapidaria. x3

Found at Foster's flats. This species is not found in any of the other deposits.

The locality at Foster's flats, where this little shell is found, is just below the old fall. At the present time, the only locality for P. lapidaria thus far discovered along the river is on the rocks in the constant rain of spray, below the present fall.

Genus VALVATA Müller. 1842

Animal with a bilobed foot, simple mantle and feather-like gills, protected by a long, slender respiratory lobe. The shell is discoidal, has a deep umbilicus and is provided with an operculum.

Valvata tricarinata Say 1822 (Fig. 168). Cyclostoma tricarinata Say (1817. *Acad. nat. sci. Phil. Jour.* 1:13). Valvata tricarinata Say (1822. *Acad. nat. sci. Phil. Jour.* 2:173)

Shell with four whorls, bearing three prominent carinae; growth lines low and indistinct; suture well impressed; umbilicus large and deep, showing the whorls to the apex; revolving lines or carinae placed one on the upper edge, one on the lower edge, and one on the base.

Fig. 168 Valvata tricarinata. x3

Found in Goat island gravel pits. As a recent shell, it is very common in the river and its tributary streams.

Valvata sincera Say (Fig. 175). Valvata sincera Say (*Long's expedition*, p. 264, pl. 15, fig. 11)

Fig. 169 Valvata sincera. x3

This shell is more globose than the foregoing and has four whorls, rounded and finely wrinkled; aperture round, not diminishing in thickness at the point of contact; umbilicus large, exhibiting the whorls to the apex.

Found associated with V. tricarinata in the gravel on Goat island.

V. sincera is not found in Niagara river at the present time, nor is it found in the immediate vicinity. Lime lake is the only locality within a radius of 50 miles known to the writer for this species.

Genus CAMPELOMA Rafinesque

Animal with a large foot; head of moderate size, situated somewhat back from the end of the foot. Shell thick and solid, oval; spire somewhat produced; surface smooth and rounded; lip simple and continuous; columellar side entirely covers the umbilicus.

Campeloma decisa Say 1817 (Fig. 170). Limnaea decisa Say (1817. *Nich. enc. Am. ed.* 1)

Fig. 170 Campeloma decisa

Shell imperforate or nearly so, oval with a smooth surface; whorls five, rounded, last whorl slightly shouldered at the suture; aperture oval; lip simple with a callus on the columellar side.

Locality. Goat island gravel pit.

Genus LIMNAEA Lamarck. 1798

Animal provided with a broad head and flattened triangular tentacles; mantle thickened in front; foot broad and flat. Shell dextral, spire oblong; aperture large and wide; the outer lip is simple, the inner has a fold on the columella.

This genus is well represented among the recent shells in this vicinity. They may be found in all the streams tributary to the Niagara.

Limnaea columella Say 1817 (Fig. 171). L. columella Say (1817. *Acad. nat. sci. Phil. Jour.* 1:14)


Fig. 171 Limnaea columella

This is a very thin, fragile shell having four whorls, rapidly diminishing, separated by a distinct but not deeply impressed suture; aperture large, more than one half the length of the shell; lip simple, and surface longitudinally wrinkled by growth lines.

Locality. Goat island gravel pits.

Only one specimen of this species was found, leading me to believe that it was an uncommon shell in early post-Pliocene times, as it is at the present time, Lime lake being the only locality in this vicinity where the recent shell occurs.

Limnaea desidiosa Say 1821 (Fig. 172). L. desidiosa Say (1821. *Acad. nat. sci. Phil. Jour.* 2:169)


Fig. 172 Limnaea desidiosa x3

Shell oblong and subconic, with five very convex whorls; suture deeply impressed; last whorl slightly swollen; slight growth lines visible with a lens.

Localities. Goat island, Whirlpool and Foster's flats.

This is the most common Limnaea found in these deposits.

Limnaea catascopium Say 1817 (Fig. 173). L. catascopium Say (1817-19. *Nich. enc. Am. ed.* p. 11, fig. 3. 1834. *Am. conch.* v 6. pl. v, fig. 2; 1841. Haldeman. *Monograph* 6, pl. 1)


Fig. 173 Limnaea catascopium

Shell thin, sculptured spirally by delicate lines, giving it a very beautiful appearance under the lens; growth lines heavy at the suture, making slight plications; whorls four or five, decreasing to an acute apex; aperture about three quarters the length of the shell; lip simple, folding back on the columellar side and leaving a narrow umbilicus.

Localities. Goat island, Whirlpool and Foster's flats.

Genus PHYSA Draparnaud

The animal of Physa is triangular in general shape; tentacles slender and setaceous; mantle covers part of the shell, the margin folding over the body whorl in a fringe. The shell is sinistral, thin, with an acute spire; body whorl large, inflated and the aperture large and oval; lip simple.

Physa heterostropha Say 1821 (Fig. 174). Limnaea heterostropha Say (1817-19. *Nich. enc. Am. ed.* pl. 1, fig. 6). Physa heterostropha Say (1821. *Acad. nat. sci. Phil. Jour.* 2:172)

Fig 174 Physa heterostropha. x3

Shell oval and smooth, sinistral; whorls four, the first large, the others very small and terminating in an acute apex; aperture large and oval, about half the length of the shell; outer lip a little thickened, inner lip folded back on the columella, forming a slight callus.

Localities. Goat island, Whirlpool and Foster's flats.

Genus PLANORBIS Guettard. 1756

The animal of Planorbis has a broad foot, and long slender tentacles. The shell is dextral and discoidal; the spire depressed, and the whorls numerous and visible on both sides; the aperture is transversely oval, with a thin lip.

Planorbis bicarinatus Say 1817 (Fig. 175). Planorbis bicarinatus Say (1817-19. *Nich. enc. Am. ed.* pl. 1, fig. 4)

Fig. 175 Planorbis bicarinatus. x2

Shell sinistral; sharply carinated on both sides; all the whorls may be seen from either side; aperture vaulted above, angulated below; surface wrinkled with growth lines at regular distances and surrounded by fine revolving striae.

Locality. Found only in the gravel on Goat island.

Planorbis parvus Say 1817 (Fig. 176). P. parvus Say (1817-19. *Nich. enc. Am. ed.* pl. 1, fig. 5). P. parvus Say (1865. *Smith. Misc. coll.* no. 144, p. 133)

Fig. 176 Planorbis parvus. x2

Shell small, with four whorls crossed by wrinkles or growth lines; concave above and below; body whorl slightly swollen; mouth oblique, with the lip simple.

Locality. Goat island and Foster's flats.

Class PELECYPODA Goldfuss

Genus SPHAERIUM Scopoli. 1777

General shape of the animal oval, margins plain, united behind and ending in two short siphons, which are joined at their base; mouth oval and small; gills broad and unequal, the inner ones largest; the foot tongue-shaped, triangular, flattened and very extensible. Shell thin, oval, often inflated, with prominent beaks;

hinge margin narrow, cardinal teeth very small or rudimentary, one of them more or less bifurcated, one cardinal tooth in the right and two oblique ones in the left valve; lateral teeth compressed and lamelliform, the anterior shortest; ligament short; margins plain; muscular impressions scarcely apparent and pallial line simple.

Fig. 177 Sphaerium striatinum. x3

Sphaerium striatinum (Lam.) Prime 1865 (Fig. 177). Cyclas striatina Lamarck (1818. *Animaux sans vertèbres*, 5:560). Sphaerium striatinum Prime (1865. *Smith. Misc. coll.* no. 145, p. 37)

Shell slight, moderately elongated, somewhat compressed, and inequilateral; anterior margin rounded; beaks full, not much raised and not sculptured; sulcations slight and irregular; hinge line curved; cardinal teeth small, double, and of the same size; lateral teeth larger, but not very prominent.

Localities. Found in all the deposits on Goat island, Foster's flats, etc.

This little bivalve is very common in the river at the present time. It is not difficult to understand how these shells were deposited, if one studies the life and habits of the recent forms. The streamlets passing among the rocks that form the Dufferin islands will be found to contain hundreds of these small shells. The bottoms of the pools formed by eddies are white with the accumulation of dead shells, in such quantities that they may be taken up by the shovelful.

Sphaerium stamineum (Conr.) Prime 1865 (Fig. 178). Cyclas staminea Conrad (1834. *Am. jour.* 25:342). Sphaerium stamineum Prime (1865. *Smith. Misc. coll.* no. 145, p. 38)

Shell oval, full and inequilateral; anterior end abrupt; posterior end somewhat distended; beaks full, prominent and sometimes sculptured; striae heavier than in the foregoing species; hinge margin more curved; cardinal teeth double, and not very distinct; lateral teeth stronger.

Fig. 178 Sphaerium stamineum. x2

In this, as in the preceding species, specimens frequently occur in which the hinge is reversed.

Localities. Goat island, Prospect park, and near the Whirlpool.

Recent species of this interesting group of fresh-water bivalves abound in Niagara river and its tributaries. While they prefer the soft mud at the bottom, they are frequently found attached to the

lower side of branches and floating debris, where they may be seen moving about by means of the long, flexible foot.

Genus PISIDIUM Pfeiffer. 1821

The animal closely resembles that of the foregoing genus, but the siphons are united to the end, those in Sphaerium being separated and more elongated. The shell is trigonal or rounded oval; the cardinal teeth are very small and double, at times they are united and are situated directly under the beaks; the lateral teeth are elongated, lamelliform, double in the right valve, single in the left; the ligament is always on the shorter side.

Pisidium virginicum (Gmelin) Bourg. 1853 (Fig. 179). Tellina virginica Gmelin (1788. ? p. 3236, pl. 159, fig. 15). Pisidium virginicum Bourg. (1853. *Am. Malac.* 1:53)

Fig. 179 Pisidium virginicum. x3

This is the largest Pisidium found in this region; it is thick and oblique; anterior side very much longer, narrower and more rounded than the posterior side, the latter being much broader and well rounded; beaks prominent and posterior; striae coarse; hinge broad and with two large cardinal teeth; laterals small and delicate.

Locality. Goat island.

Fig. 180 Pisidium compressum. x5

Pisidium compressum Prime 1851 (Fig. 180). P. compressum Prime (1851. *Bost. soc. nat. hist. Proc.* 4:164)

Shell solid, triangular and somewhat attenuated at the beaks, which are inflated; anterior side longer, narrower and more produced than the posterior; the latter subtruncate; beaks not much inflated; striae distinct and regular; hinge thick, having strong, short teeth; cardinals compressed; laterals placed at an obtuse angle with the hinge.

Locality. Goat island.

Pisidium abditum Hald. 1841 (Fig. 181). P. abditum Haldeman (1841. *Acad. nat. sci. Phil. Proc.* 1:53)

Fig. 181 Pisidium abditum. x2

Shell rounded, oval and very thin, somewhat elongated, beaks small, not inflated and placed posteriorly; surface smooth, the growth lines being indistinct; hinge nearly straight; cardinal teeth small, the anterior tooth being larger and more prominent; the lateral teeth not much elongated.

Locality. Goat island.

Pisidium ultramontanum Prime 1865 (Fig. 182). P. ultramontanum Prime (1865. *Smith. Misc. coll.* no. 145, p. 75)

Fig. 182 Pisidium ultramontanum. x3

Shell solid, oval or suborbicular, and remarkably compressed; anterior side much produced between the extremity of the lateral teeth and the junction with the basal margin; posterior margin well rounded; beaks small and only slightly raised above the outline of the shell; the striae very fine and even, and the hinge line straight.

Locality. Goat island.

Pisidium scutellatum Sterki. 1896 (Fig. 183). P. scutellatum Sterki (1896. *Nautilus,* 10:66)

Fig. 183 Pisidium scutellatum. x3

Shell high, oblique, slanting downward anteriorly, well rounded and rather strongly inflated; beaks posterior, rather large and prominent, margins well curved, the surface polished, having irregular growth lines; the hinge fine and short; cardinal teeth lamellar, the one in the right valve moderately curved, its posterior end being thickest; the inferior in the left valve curved; the superior almost straight; the lateral teeth very short, abrupt, pointed and thin, projecting somewhat into the cavity of the shell.

Locality. Goat island.

Genus LAMPSILIS Rafinesque. 1820

Shell inflated, rather thin, and shining, sometimes having a posterior ridge; sculpture coarse at beaks.

Lampsilis rectus (Lam.) Smith 1899 (Fig. 184). Unio

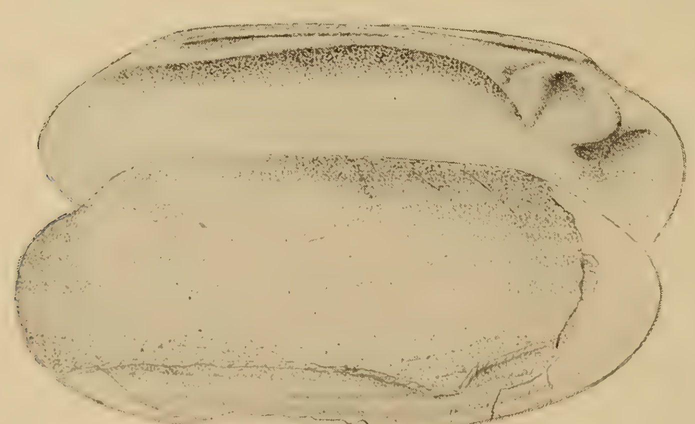


Fig. 184 Lampsilis rectus

recta Lamarck (1819. *Animaux sans vertèbres,* 6:74) Lampsilus rectus Smith (1899. *U. S. fish com. Bul.* p. 290)

Shell large, oblong, ovate, compressed and comparatively thin; surface regularly and smoothly marked by growth lines; anterior end rounded, posterior end slightly angulated; dorsal margins straight or nearly so, hollowed a little back of the beaks; ventral margin straight; adductor muscle impressions well defined; cardinal teeth not large, two on the left valve and one on the right; lateral teeth delicate; beak, in present specimen, smooth, slightly sculptured in recent specimens.

Locality. Goat island.

Lampsilis ellipsiformis (Conrad) Simpson 1900 (Fig. 185).

Unio ellipsiformis Conrad (1836. *Monograph,* 8:60)

Unio spathulatus Lea (1845. *Am. philos. soc. Proc.* 4:164)

Lampsilis ellipsiformis Simpson (1900. *U. S. nat. mus. Proc.* 22:557)

Shell oblong, very compressed, rounded both anteriorly and posteriorly; surface slightly roughened by the growth lines; dorsal

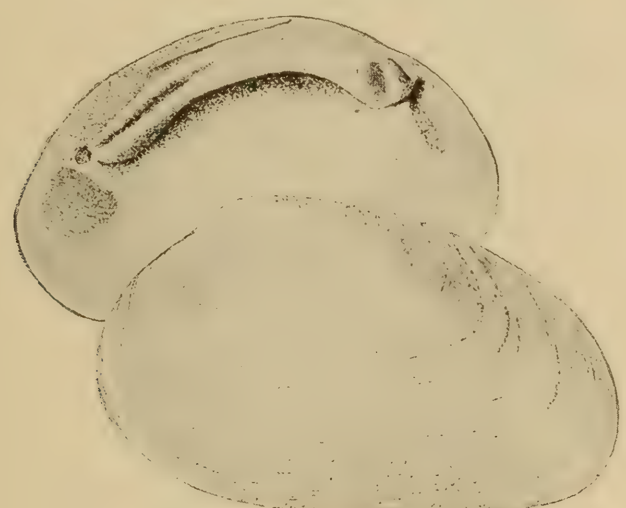


Fig. 185 Lampsilis ellipsiformis

margins curved; ventral margins angulated toward the posterior end; anterior adductor muscle impression deep and triangular, slightly pitted; posterior muscle scar broad and oval, showing the ray-like growth lines; hinge area broad and flat; teeth strong, both cardinal and lateral, there being two cardinal teeth in each valve, two lateral teeth in the left valve and one in the right; hinge area between the cardinal and lateral teeth broad and very slightly undulated; pallial line well impressed; beaks low, showing no sculpture, though recent specimens show delicate waves or ridges.

Locality. Found in Prospect park by Prof. Irving P. Bishop.

Genus ALASMIDONTA Say. 1818

The shell is ovate, solid and inflated, shining, with strong beak sculpture. Cardinal teeth thick and strong; the laterals are short, sometimes not present.

Alasmidonta calceola (Lea) Simpson 1900 (Fig. 186). Unio calceolus Lea (1830. *Philos. soc. Trans.* 3:265). Alasmidonta calceola Simpson (1900. *U. S. nat. mus. Proc.* 22:668)

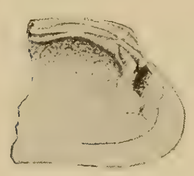


Fig. 186 Alasmidonta calceola

Shell small, solid and inflated; surface smooth; anterior end rounded; posterior end triangular; dorsal margin oval to the umbo, whence it has a deep inward curve, back of and under the beak; ventral margin straight; muscle impressions deep and well defined; pallial line clear; beaks prominent, inflated, more or less sculptured.

Locality. Goat island.

Alasmidonta truncata (Wright) Simpson 1900 (Fig. 187). Margaritana marginata var. truncata Wright (1898. *Nautilus,* 11:124). Alasmidonta truncata Simpson (1900. *U. S. nat. mus. Proc.* 22:671)

Shell elongated, quadrangular and heavy; surface marked by distinct growth lines, which are crossed by transverse wrinkles on the posterior slope; posterior end angulated; anterior end rounded; dor-

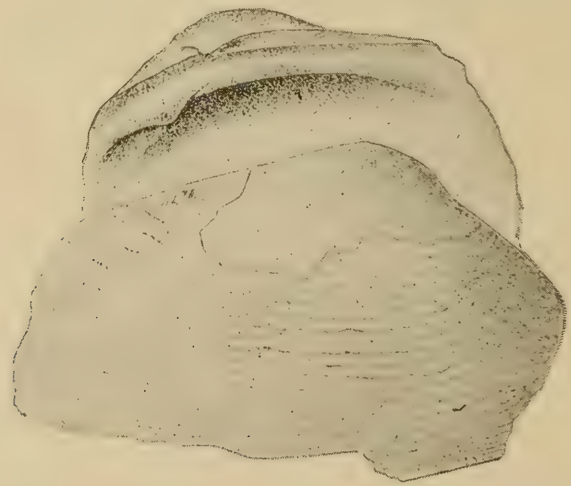


Fig. 187 Alasmidonta truncata

sal margin curved outward at the umbo; ventral margin straight or nearly so; muscular impressions deep, particularly the anterior adductor; pallial line distinct; beaks large, prominent and incurved,

having groove-like sculpture. There are three cardinal teeth, one in the right and two in the left valve; the lateral teeth are strong.

Locality. Goat island.

Genus UNIO Retzius. 1788

The shell is inequilateral, elongated, rounded in front and pointed behind, with a slight posterior ridge; beaks full, slightly sculptured; surface smooth.

Unio gibbosus Barnes 1823 (Fig. 188). Unio nasuta Lamarck (1819. *Animaux sans vertèbres,* 6:75). Unio gibbosus Barnes (1823. *Am. jour. sci.* 6:262)

Shell solid, ovate and elongated; rounded at the anterior end, angulated slightly at the posterior; dorsal margin straight or nearly so; ventral margin oval; muscle impressions deep and well defined;

Fig. 188 Unio gibbosus

teeth large and strong, the left valve having two cardinals, and two laterals; growth lines coarse; pallial line deep and clear; beaks turncated and slightly sculptured, the sculpture consisting of two or three strong ridges running parallel to the growth lines.

Found in nearly all the localities. This species seems to have been the most common of the Unios.

Genus QUADRULA Rafinesque. 1820

Shell thick, heavy and solid; teeth large and strong.

Quadrula solida (Lea) Simpson 1900 (Fig. 189). Unio solidus Lea (1838. *Phil. soc. Trans.* 6:13). Quadrula solida Simpson (1900. *U. S. nat. mus. Proc.* 22:789)

Shell oval, solid and thick, surface marked by concentric growth lines; anterior end rounded; posterior end slightly angulated; dorsal

margin oval; ventral margin sloping inward toward the posterior end; muscle impressions deep, anterior adductor muscle scar-pitted; cardinal teeth large and heavy; laterals strong and straight or nearly so, with deep, wide impressions; beaks large and prominent, showing no sculpture.

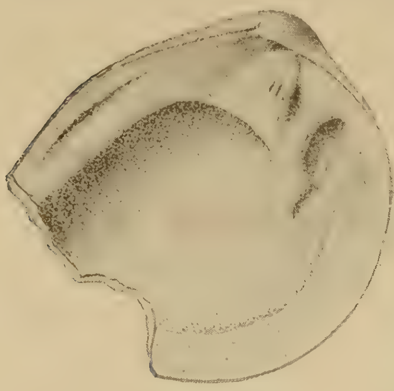


Fig. 189 Quadrula solida

Locality. From excavations in Prospect park.

Quadrula coccinea (Conrad) Simpson 1900 (Fig. 190). Unio coccineus Conrad (1836. *Monograph,* 3:29) Quadrula coccinea Simpson (1900. *U. S. nat. mus. Proc.* 22:788)

Shell quadrate, oval, thick and heavy, somewhat compressed posteriorly; anterior end oval; posterior end produced, angulated; dorsal margin oval; ventral margin rounded anteriorly, produced and pointed at the posterior end; the anterior adductor muscle impression deep, pitted above, triangular, showing radiating lines; posterior adductor impression somewhat indistinct; cardinal teeth large and strong, double in each valve; laterals strong, blade-like, two in the left valve and one in the right; beaks large, produced, showing no sculpture, and widely incurving; dorsal margin excavated at the umbones; surface marked by heavy, regular growth lines, resembling concentric waves.

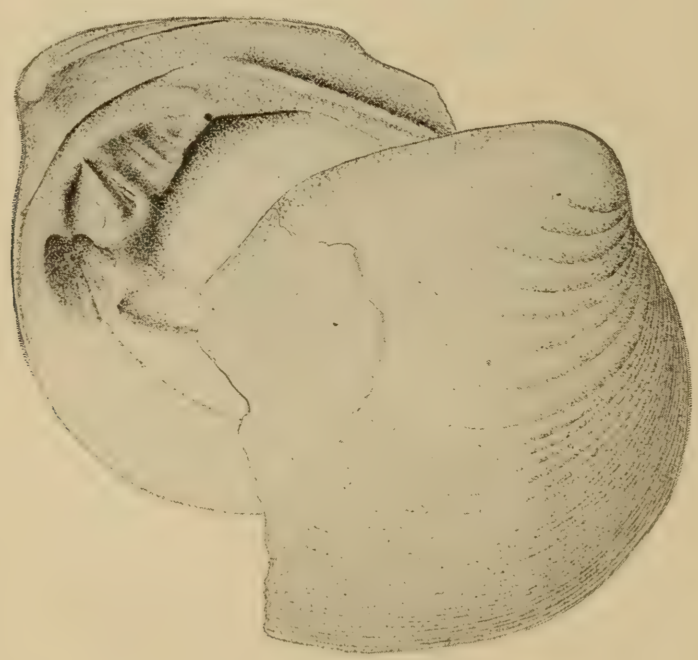


Fig. 190 Quadrula coccinea

Locality. Found in nearly all the deposits.

APPENDIX

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Glossary

aberrant—differing from the type
acanthopores—hollow spines occurring between the apertures, on the frond of a bryozoan
acinus—a berry
adductor muscles—closing muscles in bivalve shells
agglutinate—firmly united
air-chambers—chambers below the living chamber in the shells of cephalopods
alar—pertaining to wings; the lateral primary septa of the tetracoralla
alate—having wing-like expansions
ambulacral areas—perforated areas in the test of an echinoderm, through which the tubed feet project
anastomosing—uniting to form a net work
angulated—with angles or corners
ankylosed—firmly united; grown together
annulations—rings, or ring-like segments
annulus—a ring; a segment of the thorax of a trilobite
antennae—paired articulated appendages of head of arthropod—trilobite
anterior—front
aperture—opening of shells, cells, etc.
apex—terminal or first-formed portion of gastropod shells
apophysis—a calcareous process (in interior of shells, etc.)
appressed—pressed closely against
arcuate—arched; bent like a bow
articulated—joined by interlocking processes, or by teeth and sockets
asperate—rough
attenuated—tapering; or thinning
auricle—ear, or anterior projection of the hinge of many pelecypods
auriculate—eared
aviculoid—resembling Avicula, winged
axial canal—central canal of crinoid stem
axial furrows—furrows or depressions delimiting the axis in trilobites
axis—central longitudinal division of the body of a trilobite
azygous—unpaired; the azygous side of the calyx of a crinoid has plates differing from those of the regular sides

basals—lowest cycle or cycles (in forms with dicyclic base) of plates in the crinoidea
beak—area of the apex or initial point of a shell
biconvex—both valves convex, as in most brachiopods
bifid—split in two
bifoliate—two-leaved
bifurcating—dividing in two, forking

biserial—with double series or rows
brachial—pertaining to the brachia or arms of brachiopods or crinoids; one of the arm plates of crinoids
brachidium—calcareous support of the arms in brachiopods
branchiae—gills
bryozoum—whole compound colony of the bryozoa
bulbiform—bulb-shaped
byssal notch—notch or opening for the emission of the byssus (supporting-threads spun by the foot) in the pelecypoda

calicinal—pertaining to the calyx or cup
callosity—hardened spot or area
callus—thickened part of the inner lip of gastropods, which usually covers portions of the preceding volutions
calyx—1) cup of corals, limited below by the septa; 2) body, exclusive of the arms, of crinoids, cystoids and blastoids
camerate—chambered; an order of crinoidea
camerae—air-chambers of a cephalopod shell
canaliculate—channeled; having a canal
cancellated—marked by lines crossing each other; lattice-like
carapace—hard shell or shield of crustacea
cardinal—pertaining to the area of the beak in brachiopods and pelecypods
cardinal process—process from under the beak of the brachial valve of brachiopods, to which the diductor (opening) muscles are attached
cardinal quadrants—two quadrants of a Tetracorallum which bound the main, or cardinal, septum
cardinal septum—first or main of the four primary septa of a Tetracorallum; the cardinal septum has the pinnate arrangement of the secondary septa on both sides
cardinal teeth—teeth under the beak in the pelecypods; teeth in the pedicle valve of the brachiopods
carina—projecting ridge running down the center of the branches in some fenestelloid and other bryozoa; the projecting ridges on the septa of Heliophyllum and other corals
carinated—having a ridge or keel
cartilage—compressible, elastic substance between the hinge-margins of the valves of pelecypods. The cartilage is the internal, as the ligament is the external medium for opening the valves
cast—the impression taken from a mold
caudal—pertaining to the tail
celluliferous—cell bearing (bryozoa commonly have a celluliferous and a non-celluliferous side)
cephalic limb—anterior border of the cephalon of a trilobite
cephalon—head-shield of trilobites
cephalothorax—combined head and thorax of crustacea
cercopods—lateral tail spines in the ceratiocarida

cespitose—matted, tangled or growing in low tufts
cheeks—lateral portions of the cephalon, divided into fixed and free cheeks, of a trilobite
chelae—pincer-like claw terminating some of the legs of crustacea
chilidium—covering for the chilyrium
chilyrium—triangular opening under the beak of the brachial valve in those brachiopods in which that valve is furnished with a hinge area
chitinous—composed of chitin, the substance forming the horny wings or elytra of beetles, and the carapaces of crustacea
cicatrix—a scar
cincture—depression anterior to the beak in the shell of some pelecypods
cirri—root-like appendages to the stem of crinoids
clastic—consisting of fragments, i. e. rocks made of fragments of older rocks
clavate—club-shaped
clavicle—heavy internal ridge running downward from the beak in some pelecypods
columella—central or axillary rod
compound corallum—made up of corallites, either separate or closely joined by their walls (ex. Favosites)
composite corallum—compound corallum with coenenchyma or extrathecal calcareous tissue connecting the corallites (ex. Galaxia and many other recent forms)
concavo-convex—shells of brachiopods are normally concavo-convex, when the brachial valve is concave, and the pedicle valve convex; reversed or resupinate, when the reverse condition obtains
confluent—blended so that the line of demarcation is not visible
coniferae—order of arborescent plants to which the pines, firs, etc. belong
consequent stream—type of stream which flows down the original constructional slope of the land
corallites—individual tubes of a compound corallum
corallum—calcareous skeleton of a single, or of a colonial, coral stock
corneous—horny
coronal—crown-like
costae—extrathecal extensions of the septa of the corals
costals—first brachial or arm-plates of the crinoids lying between the radials and the first bifurcation of the arms
counter quadrants—quadrants bounding the counter septum of a Tetracorallum
counter septum—front primary septum of the Tetracoralla, opposite the cardinal septum; the secondary septa are parallel to it
crenulated—notched to produce series of teeth
crura—apophyses to which the brachidium of the brachiopods is attached
cuesta—topographic relief element, resulting from the normal dissection of a coastal plain composed of alternating harder and softer strata (see p. 40)

cuneate—wedge-shaped
cuneiform—wedge-shaped
cyathophylloid—in form like Cyathophyllum; one of the Tetracoralla
cyst—a closed cavity
cystoid—most primitive class of Pelmatozoa or stemmed echinoderms

delthyrium—triangular fissure under the beak of the pedicle valve of the brachiopoda
deltidium—single covering plate of the delthyrium (also called pedicle plate)
deltidial plates—two plates which close the delthyrium in the higher brachiopoda (Telotremata)
dendroid—branching after the manner of a tree
dental plates—internal plates below the teeth in pedicle valve of the brachiopoda
denticles—small teeth, or tooth-like ridges
denticulate—toothed
denticulation—set of denticles or small teeth
depressed—on a level with, or below the general surface
dextral (right handed)—the normal method of coiling in the gastropoda
diaphragm—transverse partitioning plate
dicyclic—with two cycles of basals; applied to crinoids
diductor muscles—opening muscles of the brachiopoda
discinoid—resembling Discina
discoid—disk-like
dissepiments—partitions; the intrathecal connecting plates between the septa of the corals; the connecting bars between the branches of a fenestelloid bryozoum
distal—situated away from the center of the body
distichals—second series of arm plates or brachials of crinoids, situated above the axillary costals
divaricators—opening muscles of brachiopoda; also called diductors
dorsal—pertaining to the back
doublure—infolded margin of a trilobite

ear—anterior cardinal expansion of the pelecypod shell, usually smaller and more distinctly defined than the posterior expansion or wing
echinate—spinous
endoderm—inner cellular body layer
emarginate—with a notched margin
endoderm—inner cellular body layer
endothecal—within the theca; intrathecal; used for corals
epicontinental—encroaching on the continent
epidermal—pertaining to the skin
epitheca—outer calcareous covering of a corallum or bryozoan
equilateral—with similar sides
equivalve—with similar valves
escharoides—like Eschara (a bryozoan)

escutcheon—depression behind the beak of the pelecypod shell
exfoliate—peeling off
exothecal—outside of the theca of corals
explanate—spread out in a flat surface
extrathecal—outside of the theca of corals
extroverted—turned base to base; applied to spirals of brachiopods

facetted—having facets or numerous faces as the eye of an insect, etc.
facial sutures—sutures in the cephalon of trilobites which separate the free from the fixed cheeks
facies—local characteristics
falcate—curved like a scythe or sickle
fasciculate—clustered
fathom—a measure of length equaling 6 feet used chiefly for depths of the sea
fenestrule—open spaces between the branches and dissepiments of a fenestella frond
filament—a fine thread or fiber
fimbriae—a fringe
fixed cheek—that part of the cephalon of a trilobite which lies between the glabella and the facial suture
fission—the act of splitting or cleaving into parts
flabellate—fan-shaped
flange—a projecting rim
flexibilia—an order of crinoids characterized by the loose jointing of the plates of the calyx
fold—the central elevation of the valve, usually the brachial of a brachiopod
foliate—leaf-like; in the form of a thin leaf-like expansion
foramen—an opening or pore; specifically the opening for the pedicle in the pedicle valve of the brachiopoda
fossula—groove in the calyx of a coral, usually due to the abortion of a septum
free cheeks—lateral portions of the cephalon of trilobites separated off by the facial sutures
frond—foliaceous or leaf-like expansion of the skeleton of bryozoa and other organisms
fruticulose—resembling a small shrub
fucoid—a seaweed, particularly of the type similar to the modern Fucus, or rockweed

galeate—with a helmet-like covering
gastric—pertaining to the stomach
genal angles—posterior lateral angles of the free cheeks of trilobites
genal spines—posterior prolongations, or spines, of the free cheeks of trilobites
geode—a hollow concretion usually lined with crystals, but also filled completely with foreign mineral matter

geodiferous—containing or abounding in geodes
geodetic—geode-bearing, pertaining to geodes
gibbous—swollen or humped
glabella—central, most prominent portion of the trilobite cephalon, bounded by the fixed cheeks
glomerate—growing in dense heads or clusters, generally of an irregular character
gonopolyp—reproductive polyp of Hydrozoa
granulated—having small and even elevations resembling grains
granulose—bearing or resembling grains or granules

hexacoralla—class of corals built on the plan of six
hinge area—flat area bordering the hinge line of many brachiopods
hinge line—line of articulation
hydrocoralline—order of Hydrozoa which build calcareous skeletal structures
hydroid—animal belonging to the class of Hydrozoa
hydrotheca—cup inclosing the nutritive polyp in thecaphore Hydrozoa
hyponome—water tube, or squirting organ, of squids, cuttlefish, and other cephalopods
hypostoma—underlip of the trilobites, usually found detached

imbricate—overlapping serially
implantation—planting between, as a new plication suddenly appearing between two older ones
inarticulate—not articulating by teeth and sockets; of brachiopoda
incised—cut into
incrusting—covering as with a crust
inequilateral—having unequal sides
inface—steep face or escarpment of a cuesta, facing toward the old-land
inferior—lower in position
inflated—distended in every direction and hollow within
inflected—bent or turned inward or downward
infrabasals—lower cycle of basal plates in the crinoids with dicyclic base
infundibuliform—funnel-shaped
inosculating—connecting, so as to have intercommunication
interambulacral—between the ambulacra
interapertural—between the apertures
interbrachials—plates in the calyx of a crinoid, lying between the brachials
intercalation—irregular interposition
intercellular—between the cells or meshes
interdistichals—plates in the calyx of a crinoid, lying between the distichals
interradials—plates in the calyx of a crinoid, lying between the radials
interstitial—pertaining to an intervening space; between lines, plications, etc.
intervestibular—between the vestibules or circumscribed areas
interzooecial—between the zooecial tubes in bryozoa, etc.

intrathecal—within the theca; endothecal
introverted—turned apex to apex; applied to the spirals of brachiopods
involute—rolled up, as a Nautilus shell

joints—component segments of the stem of a crinoid
jugum—yoke-like connection between the two parts of the brachidium of a brachiopod

keel—strong central carina or ridge (Taeniopora)

lacrymiform—tear-form; drop shaped—pear shaped, but without the lateral contractions
lamellar—disposed in lamellae or layers
lamellibranch—leaf-gilled, the class of molluska with bivalved shell, to which the oyster and clam belong; pelecypod
lamelliform—having the form of a leaf or lamella
lamellose—made up of lamellae
lamina—a thin plate or scale
lateral gemmation—a budding from the sides, as in some corals
lateral teeth—ridge-like projections on either side of the beak, in the interior of lamellibranch shells
laviformia—primitive order of crinoids
ligament—external structure for opening the valves in the pelecypoda
limb—lateral area or marginal band of the cephalon of trilobites on either side of the glabella, corresponding to a pleuron of the thoracic region
lines of growth—lines marking the periodic increase in size, in shells
linguiform—tongue-shaped
linguloid—tongue-shaped; like Lingula
lip—margins of the aperture of univalve shell
listrium—depressed area surrounding the pedicle opening in the pedicle valve of Orbiculoidea and other discinoid brachiopods
lithic—pertaining to stone
living chamber—the last chamber in the shell of a cephalopod, which is occupied by the animal
lobes—backward bending portions of the suture of cephalopod shells
lophophore—ciliated or tentaculated, oral disk of bryozoa; the oral disk and brachia of brachiopods
lunarium—more or less thickened portion of the posterior wall of the cell in many paleozoic bryozoa, which is lunate or curved to a shorter radius, and usually projects above the plane of the cell aperture
lunule—depression in front of the beak of pelecypod shells

macerate—softening and disintegrating by immersion in water
macrocorallites—the larger corallites in a compound corallum
maculae—irregular, usually depressed, areas on the celluliferous face of a bryozoan frond, which are free from cells, or otherwise differentiated
mandibles—first upper or outer pair of jaws of crustacea and insects

mantle—fleshy membrane infolding the soft parts of mollusks and brachiopods and building the shell
medullary rays—the " silver grain " or radiating vertical bands or plates of parenchyma in the stems of exogenous plants
medusa—a jelly fish
membranaceous—pertaining to a membrane
mesial—central
mesogloea—central, non-cellular layer in the body of coelenterates
meso-pores—irregular meshes or cysts on the intercellular spaces of certain bryozoa
mesotheca—median wall separating opposed cells in certain bryozoan fronds
metastonia—underlip of crustacea, composed of small pieces immediately below and behind the mouth
microcorallites—smaller corallites of a compound corallum
mold—any impression of a fossil, in rock matrix, external or internal
moniliform—resembling a necklace or string of beads
monocyclic—of a single cycle
monticuliporoids—corals belonging to the order Monticuliporidae having many points of resemblance with the bryozoa
monticules—elevated areas on the surface of certain coral and bryozoan colonies, commonly carrying larger apertures
mucronate—produced into a long pointed extension
mural pores—pores in the walls of the corallites of the Favositidae
muscle scar—scar in a shell marking the former attachment of a muscle

nacreous—pearly; the nacreous layer of shells is the inner smooth pearly layer
nariform—shaped like a nostril
nasute—projecting, nose-like
nettlecell—one of the nematocysts or stinging cells found covering the tentacles and other body parts of most Coelenterata
node—knob; usually considered as ornamental
nodose—bearing nodes or tubercles
nodulose—knotty, or having nodes

obconical—inversely conical
oblate—flattened at the poles
obovate—inversely ovate or egg-shaped
obsequent stream—a stream flowing down the inface of a cuesta, or toward the old-land, tributary to the subsequent stream which in turn flows into the consequent
occipital—applied to the posterior part of the cephalon of a trilobite
occipital furrow—transverse groove on the cephalon of trilobites, which separates the last or occipital ring from the rest of the cephalon
occipital ring—posterior division of the glabella of a trilobite cephalon
operculiform—resembling an operculum
operculum—lid or cover

paddles—large or last pair of thoracic legs of the eurypterids

pallial line—line on the interior of the shell of mollusks marking the attachment of the mantle

pallial sinus—reentrant angle in the pallial line usually at the posterior end of the shell of pelecypods; it marks the attachment of the siphon muscles

palmars—third series of brachial plates of the Crinoidea, lying above the axillary distichals

palmate—palm-shaped

palpebral lobes—supra-orbital extensions from the fixed cheeks of trilobites

papilla—a small nipple-shaped protuberance

papillose—covered with papillae or fine projections

parabasals—second cycle of basal plates in crinoids

pectinated rhombs—paired pore clusters in the calyx of certain cystoids (Callocystites)

pedicle—fleshy peduncle or stem used for attachment in the brachiopoda

pedicle valve—valve which gives emission to the pedicle in the brachiopoda. Ventral of most authors. Usually the larger valve

pentameroid—five chambered, similar to Pentamerus

pentapetalous—resembling a five-petaled flower

penultimate—next to the last

periderm—outer chitinous covering of Hydrozoa

periostracum—epidermis or outer organic coating of shells

peripheral—pertaining to the circumference

peristome—margin of an aperture, i. e. the mouth of a univalve molluscan shell, the mouth of a bryozoan cell, etc.

peritheca—epithecal covering which surrounds a colony of corallites, i. e. a compound corallum

petaloid—resembling a leaf or petal

pinnate—shaped like a feather

pinnulate—provided with pinnules

pinnules—finest divisions of the arms of crinoids

plano-convex—normally in brachiopods, with the pedicle valve convex and the brachial valve flat

pleura—lateral portions of the thoracic rings of trilobites

plicate—plaited or folded

plications—folds or rib-like plaits of a brachiopod shell

polyp—animal of a simple coelenterate or bryozoan

polypite—individual polyp of a colony

pore-rhombs—pore clusters, arranged in rhombic manner in the calyx of cystoids

poriferous—pore-bearing, corals which like Favosites are furnished with several pores

posterior—situated behind

post-palmars—all the plates, superior to the axillary palmars in the arms of crinoids
prehensile—adapted for seizing
preoral—situated in front of the mouth
produced—drawn out, elongated
proliferous—reproducing buds from the calyx
protoconch—embryonic shell of a cephalous molluscan
proximal—nearest or basal portion
pseudocolumella—false columella in corals, formed by a twisting of the septa
pseudodeltidium—false deltidium (Spirifer), formed by union of the two deltidial plates
pseudosepta—septa-like ridges of Chaetetes, etc., the projecting ends of the lunaria in the cells of certain bryozoa
pseudotheca—false wall or theca in some corals, formed by the expansion of the outer margins of the septa
punctate—dotted, with scattered dots or pits
pustule—small blister-like elevation
pustulose—bearing pustules or projections
pygidium—posterior or tail portion of the carapace of trilobites
pyramidal—having the form of a pyramid
pyriform—pear-shaped
pyriformis—pear-shaped

quadrangular—four angled
quadrate—with four equal and parallel sides
quadrifid—cut into four points
quadrilobate—bearing four lobes
quadriplicate—with four folds
quincunx—five objects arranged in a square with one in the middle

rachis—central stem of a frond in bryozoa, etc.
radials—main plates of the calyx of a crinoid, resting on the parabasals, and alternating with them
radii—ribs or striations diverging from the beak of a shell
ramose—branching
ramus—branch of a skeletal structure
reniform—kidney form
resilium—internal cartilage or compressible substance in the hinge of pelecypods
reticulated—like a network
retractile—capable of being withdrawn
retral—backward
rhynchonelloid—resembling Rhynchonella
root—expanded basal portion of a crinoid stem, used for fixation
rostrum—a beak or snout
rugosa—an old name for the Tetracoralla

saddles—forward bending portions of the suture in the shells of cephalopods
salient—standing out prominently
scabrous—rough or harsh with little projecting points
scalae—small transverse plates in the genus Unitrypa of the bryozoa
scalariform—stair or ladder-shaped
sclerenchyma—calcareous tissue deposited by the coral polyps
scorpioid—scorpion-like, coiled like the tail of a scorpion
semilunar—crescentic, or resembling a half moon
semiovate—half egg-shaped
senile—pertaining to old age
septal radii—radiating ridges taking the place of septa in certain corals
septate—with partitions or septa
septum—partition; in corals, the radiating calcareous plates; in cephalopods, the transverse partitions between the chambers
serrate—notched like a saw
setiferous—bristle-bearing
sigmoid—curved like the Greek letter Σ (sigma)
sinistral—left handed, reversed coiling of some gastropod shells
sinuate—wavy, winding
sinuosity—notch or incision forming a wavy outline
sinus—impression in the surface or margin of a shell
siphonal funnel—siphonal projection from the septum of a cephalopod shell
siphonal lobe—lobe in the suture of an ammonoid shell, corresponding in position to the siphuncle
siphuncle—tubular canal passing through the air chambers in the shells of cephalopods
slickensides—polished or striated surfaces on rock due to motion under great pressure
sockets—hollows in the brachial valve of brachiopods for the reception of the teeth of the opposite valve
spatulate—shaped like a spatula; spoon-shaped
spheroidal—globose, of the form of a spheroid
spiniform—spine-like
spinulose—spine bearing
spondylium—spoon-shaped cavity under the beak of pentameroid brachiopods
squamous—scaly, covered with scales
stalk—stem of crinoids
stellate—star-shaped; arranged in star-like manner
stipe—stalk or stem in plants
stock—main stem or trunk
striae—fine radiating surface lines of shells
stylolites—peculiar columnar and striated rock form seen in limestones at the junction of two layers
sub—in composition indicates a low degree: sub-angular—rather angular; sub-carinate—somewhat toothed, etc.

subfusiform—more or less spindle-shaped
subglobose—more or less globose
sublunate—approaching the form of a crescent
suborbicular—nearly circular
subpentahedral—irregularly five-sided
subpyramidal—approximately pyramid-shaped
subquadrangular—between quadrangular and oval
subquadrate—nearly but not quite square
subspheroidal—imperfectly spheroidal
subtruncate—irregularly cut off
subturbinate—approaching top shape
sulcation—a furrow or channel
sulcus—a furrow
superior—higher in position
suture—in cephalopods, the line of junction between shell and septum, seen on breaking away the former; in gastropods, the external line of junction between the several whorls; in trilobites, the dividing line between fixed and free cheks, commonly called *facial suture;* in crinoids, the line of junction between adjacent plates

tabulae—transverse, continuous partitions or floors in corals, etc.
tabulate corals—group of corals in which the tabulae cross plates are prominent, while the septa are faintly or not at all developed e. g. Favosites, Aulopora, etc.
talus—the mass of rocky debris which lies at the base of a cliff, having fallen from the face of the cliff above
teeth—articulating projections on the margins of the valves of bivalve shells
tegmen—vault or cover of the calyx in crinoids
terebratuloid—like the recent genus Terebratula
terete—cylindric or slightly tapering terrigenous—derived from the land test-shell
tetracoralla—the old group of rugose corals, built on the plan of four
tetrameral—on the plan of four
theca—the proper wall of the individual corals
thoracic—pertaining to the thorax
thorax—central part of the body of the trilobites
trabeculae—projecting bars
trigonal—three-angled
trihedral—with three equal faces
tripartite—divided into three parts
tripetalous—three leaved or petaled
trochiform—in form like a Trochus or top shell
tubercle—small swollen projection
tuberculiform—in form like a tubercle
tuberculous—having or resembling tubercles
tubicola—an order of marine worms which build calcareous or other tubes
tumid—swollen, inflated
turbinate—top-shaped

umbilicus—external opening of the hollow axis of a loose coiled shell
umbo—area about and including the beak in pelecypods and brachiopods
unconformity—irregularity in the succession of rock beds indicating an intervening period of erosion

valvular—pertaining to a valve
varix—row of spines, a ridge or other mark, denoting the former position of the lip on the shell of a gastropod (plural varices)
vaulted—arched
ventral—pertaining to the lower side, or venter
ventricose—strongly swollen, or bulging
vesicular—bearing vesicles, or hollow cavities
vestibular area—area surrounding the cell apertures of some bryozoa; often depressed
viscera—the internal organs of the body

whorl—single volution of a coiled shell
wing—posterior larger expansion along the hinge-line of a pelecypod

zoarium—aggregates of the polypites of a bryozoan colony
zooecium—the bryozoan cell
zooid—one of the "persons" or individuals of a zoarium

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